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Japan Report

SCIENCE AND TECHNOLOGY

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JAPAN REPORT

SCIENCE AND TECHNOLOGY

CONTENTS

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AEROSPACE SCIENCES

OVERVIEW OF JAPAN'S SPACE POLICIES, PROJECTS

Japan's Space Development Policy

Tokyo PUROMETEUSU in Japanese Jan 87 pp 36-71

[Article by Space Development Division, Research & Development Bureau, Science & Technology Agency: "Practical Utilization of Space"]

[Text] Introduction

Japanese exploration and development of space is conducted, while maintaining national continuity, according to comprehensive planning that is based on the Space Development Plan which is formulated each year as a specific policy statement in keeping with the Space Development Policy Guidelines established by the Space Activities Commission. In the organizational framework within which this work is conducted, the Science & Technology Agency, Ministry of Education, Ministry of International Trade & Industry, Ministry of Transport, and Ministry of Posts & Telecommunications draft policies under the regulatory oversight of the Space Activities Commission. The National Space Development Agency (NASDA) conducts space development in areas of practical applications, while the Space Science Research Institute conducts space development in scientific fields.

The government budget for space development is determined each year according to estimates provided by the Space Activities Commission. The budgeted amounts for fiscal 1986, and the estimated budget amounts requested for fiscal 1987, are given in Table 1. The portion of this budget earmarked for NASDA is as noted in Table 2, constituting more than 80 percent of the national space budget. Thus NASDA is the primary implementational organization for Japanese space development.

The history of Japanese space development in the area of practical applications began in 1975 with the technology-testing satellite "Kiku" which was launched by a NADSA N-I rocket. Subsequently, we have launched 15 satellites, which have made large contributions in such fields as communications & broadcasting, and meteorological observation. Meanwhile, Europe and America were moving up to the stage of diverse space utilization, conducting remote sensing with the LANDSAT satellites, performing space experiments with the space shuttle, and making commercial satellite launches with the Arianne rocket. Japan, however, has completed the stage where priority

was given to consolidating space development fundamentals, and is now at the stage where it should promote diverse plans for the practical utilization of space.

Table 1 Space Development Expenditures for Fiscal 1987
(<B> indicates limits for financing with treasury bonds)
(Unit = 1000 yen)

1986 Budget

Ministry/Agency	Space Development	Space Related*	Total
Science & Technology Agency	<B> 78,469,160 92,582,190	—	<B> 78,469,160 92,582,190
National Police Agency	—	328,406	328,406
Ministry of Education	<B> 3,956,000 8,386,944	<B> 3,000,000 3,988,078	<B> 6,956,000 12,375,022
MITI	6,078,205	---	6,078,205
Ministry of Transport	<B> 8,249,880 2,656,496	<B> 71,438 2,422,388	<B> 8,321,318 5,098,884
Min of Posts & Telecom	<B> 385,100 385,354	392,661	<B> 385,100 778,015
Ministry of Construction	—	2,030	2,030
Ministry of Home Affairs	—	137,632	137,632
Totals	<B> 91,060,140 110,089,189	<B> 3,071,438 7,291,195	<B> 94,131,578 117,380,384

1987 Budget

Ministry/Agency	Space Development	Space Related*	Total
Science & Technology Agency	<B> 110,788,140 95,941,218	—	<B> 110,788,140 95,941,218
National Police Agency	—	147,790	147,790
Ministry of Education	<B> 7,589,500 7,005,010	<B> 5,386,000 5,920,897	<B> 12,975,500 12,925,907

Table 1 (continued)

MITI	8,408,842	---	8,408,842
Ministry of Transport	<B> 374,520 3,551,939	2,797,729	<B> 374,520 6,349,668
Min of Posts & Telecom	<B> 115,000 463,098	266,540	<B> 115,000 729,638
Ministry of Construction	___	2,028	2,028
Ministry of Home Affairs	___	112,936	121,936
Totals	<B> 118,867,578 115,370,107	<B> 5,386,000 9,256,920	<B> 124,253,160 124,627,027

* Communications satellite utilization costs and other space-related expenditures (those outside of the range of the estimates made by the Space Activities Commission) are included here for reference.

Table 2 NASDA Budget Requests for Fiscal 1987
(National Treasury basis, units = million yen)

Item	1986 Budget (Approved Amt)	1987 Budget (Requested Amt)
National Space Development Agency (Breakdown)	<B> 78,322 90,659	<B> 110,641 94,021
1. H-I Project	<B> 29,314 38,592	<B> 20,245 33,816
H-I rocket development (To be launched summer, 1987 (ETS-V/TF#3))	11,219	4,737
Technology-test satellite model V (ETS-V) (To be launched summer, 1987 (ETS-V/TF#3)	2,635	3,238
Communications satellite No. 3 (CS-3) (To be launched winter, 1987, or summer, 1988)	<B> 795 4,544	4,928
Marine observation satellite No. 1 (MOS-1) (To be launched winter, 1988)	5,607	2,777 936

Table 2 (continued)

Broadcast satellite No. 3		1,425	<B>	4,426
(BS-3)				2,386
(To be launched winter, 1990, or summer, 1991)				
Geostationary meteorological satellite No. 4 (GMS-4)	<B>	5,500	<B>	250
		1,387		2,185
(To be launched summer, 1989)				
Earth resource satellite No. 1	<B>	8,441	<B>	7,555
(ERS-1)		3,710		5,620
(To be launched winter, 1990)				
Common to H-I	<B>	14,578	<B>	5,237
		8,065		9,786
2. H-II Project	<B>	47,458	<B>	55,606
		23,263		34,844
H-II rocket development	<B>	38,761	<B>	40,501
		21,454		30,026
(To be launched winter, 1991 (TF#1)				
Technology-test satellite Model IV	<B>	3,011	<B>	9,925
(ETS-VI)		378		2,361
(To be launched summer, 1992)				
Common to H-II	<B>	5,686	<B>	5,180
		1,431		2,457
3. Space Station Master Project			<B>	33,316
		10,154		8,215
Space Station Project			<B>	32,946
		4,110		6,311
(To be launched in 1994)				
Space Experiment Project (FMPT)		6,044		1,375
SSIP-related research			<B>	370
		0		529
4. Research & Development Projects			<B>	1,474
		4,011		4,149
5. Earth Observation Projects	<B>	1,550		
		2,061		2,554
6. Operations & Administration, Etc.		12,578		10,443

We present in this article a brief look at the current status of, and future outlook for, Japanese space utilization.

Present Status, Outlook for Space Utilization

1. Rockets

The first step in utilizing outer space is in launching materials into space. Japanese launch vehicles for the practical utilization of space are based on Delta rocket technology obtained from the United States, and have developed from the N-I, to the N-II, and on to the H-I rockets. The H-I rocket successfully launched an experimental device in August, 1986. Delta technology is still used in the first stage of this launch vehicle, but a liquid-oxygen, liquid-hydrogen rocket developed in Japan is used in the second stage, which also carries an inertial guidance system that is completely Japanese produced. Hence Japan's space technology has reached world-class levels. Nevertheless, most of our communications satellites and other practical satellites in stationary earth orbit are in the 1-ton class, and it must be admitted that the H-I, having a 550-kg launch capability, is inadequate for the practical utilization of space.

The H-II rocket, on which development work began in fiscal 1986, has a 2-ton launch capacity, and all of its stages are based on technology developed in Japan. This rocket is being designed to achieve launch costs on a par with those of the space shuttle and Arianne systems. An experimental vehicle is scheduled for launch in fiscal 1991. It is ardently hoped that this rocket will provide a vehicle for truly practical space utilization for the early 1990's.

Figure 1 Artificial Satellite Launch Schedule

Key to Figure 1:
1. Item / Year
2. N-II Project
3. H-I Project
4. H-II Project
5. Space Station Master Project
6. Development of H-II rocket
7. Development of JEM
8. (dark arrow) Decided
9. (shaded arrow) Development desired
10. (white arrow) Conjectured

* Satellite Names, Nomenclature

MOS-1,1b:	Marine Observation Satellite No. 1
ETS-V:	Technology-Testing Satellite Model V
CS-3a,3b:	Communications Satellite No. 3
GMS-4:	Geostationary Meteorological Satellite No. 4
BS-3a,3b:	Broadcast Satellite No. 3
ERS-1:	Earth Resource Satellite No. 1
ETS-VI:	Technology-Testing Satellite Model VI
T.F.:	Test flight
FMPT:	First materials experiments
GTV:	Ground test vehicle
PL:	Payloads modified for flight on models with ETS-VI configuration (EM level)
SFU:	Space experiment/observation free-flier
IML:	International Minute-Gravity Laboratory
POP:	Polar orbiting platform (America, Europe)
JEM:	Laboratory module for attachment to space station
STS:	Space transport system (using space shuttle)

(fancy asterisk 1)	EGP (geodetic experimental function part) + JAS - 1 (Japan Amateur Satellite No. 1) + MBFW (magnetic-bearing flywheel)
(fancy asterisk 2)	Carries experimental mobile communications equipment
(fancy asterisk 3)	Implementation period extended (due to January, 1986, shuttle accident)
(fancy asterisk 4)	Double launch with SFU (conjectured)

2. Communications, Broadcasting

Satellite communications based on state-of-the-art space utilization have now become essential for the maintenance of communications in today's world.

Japan launched the CS-2a and CS-2b (Sakura 2-a, 2-b) satellites in February and August of 1983, respectively. These devices are now being used by NTT and governmental agencies for emergency communications and remote-island communications. As a follow-up device, the CS-3 is now under development and scheduled for launch in fiscal 1987 or 1988.

As communications satellites become larger and of greater capacity in the future, new demand for satellite communications is expected to open up in the field of mobile communications for ships, aircraft, and automobiles. The Model-VI technology-testing satellite is scheduled for launch aboard an H-II rocket in fiscal 1992. The Model-VI is being designed to implement advanced satellite communications technology for mobile applications.

Meanwhile, Japan was the first in the world to orbit a broadcast satellite, launching the BS-2a (Yuri 2-a) in January, 1984, aiming at individual broadcast applications, but success was limited to test broadcasting due to failure of an onboard relay device, and hopes are now focused on the Yuri 2-b which was launched in February, 1986. As a successor satellite, the BS-3, which implements 3-channel broadcasting, is now under development and scheduled for launch in 1990 or 1991.

3. Meteorological Observation

In the field of meteorological observation, observations are now being conducted with a number of weather satellites through international cooperation. Japan is involved in this field with its geostationary meteorological satellite (GMS) "Himawari." We are now up to "Himawari 3," our third weather satellite, launched in 1984. This satellite provides information of cloud distribution and temperatures at sea level, ground level, or at cloud tops, etc. This information is being effectively used by Australia and other Asian nations in addition to Japan. The successor will be the GMS-4, scheduled for launch in fiscal 1989.

4. Earth Observation / Remote Sensing

In order to comprehensively monitor the conditions of sea and land regions, it is best to use earth observation satellites that use various sensors to observe broad areas of the globe while orbiting the earth. This is called remote sensing.

Since 1979, NASDA has been receiving earth observation data from U.S. LANDSAT satellites and providing this information to users.

Meanwhile, developmental work is progressing on the Marine Observation Satellite No. 1 (MOS-1), Japan's own earth observation satellite, which is to be launched in 1986 and is designed to conduct observations on the color and temperature of sea surfaces and other oceanic phenomena. In 1986 development work was begun on the Earth Resource Satellite No. 1 (ERS-1), which is scheduled for launch in fiscal 1990. The objectives for this satellite include the perfection of active observation technology using compound aperture radar, resource exploration, observations for agricultural, forestry, and fishing industries, and observations for environmental protection.

In Europe and the United States, in order to conduct earth observations more efficiently and reliably, plans are being made to launch a polar

orbiting platform sometime during the 1990's as part of the space station project (described below). Japan is also interested in participating in this project, and is presently proceeding with research on advanced sensor technology, etc.

In view of these recent activities in the remote sensing field, the Science & Technology Agency formed the "Remote Sensing Promotion Conference" (headed by Kiyoshi Tsuchiya, professor at Chiba University) in its Research & Development Bureau. This conference is to study (1) specific, long-range plans pertaining to Japan's remote sensing activities, (2) earth observation projects to come after ERS-1, and (3) Japan's participation in the polar orbiting platform project of Europe and America. It is believed that the field of remote sensing will play an increasingly important role in space utilization in the future.

5. Space Station Master Project

The utilizations of space which have been discussed thus far make use of the altitude and orbital revolutions of satellites. In other words, they make use of the position of a vehicle in space. The Space Station Master Project, however, makes use of weightlessness and other unique aspects of the space environment.

This project, which will be conducted by the Science & Technology Agency and NASDA, is designed to pioneer the new field of space environment utilization, developing such multifaceted constituent elements as free-fliers, co-orbital platforms, polar orbiting platforms, and orbital work vehicles, primarily based on the main space station unit, but including the field of space experiments. The project will be implemented using human resources drawn from industry, academia, and government.

(1) First Materials Experiment

By using such peculiarities of the space environment as super-vacuum and weightlessness, researchers hope to manufacture superior materials and pharmaceutical products which cannot be obtained on earth. A number of experiments have already been performed using space labs on board the U.S. space shuttles. Researchers in Japan have been moving ahead with the FMPT project in which 34 experiments are to be done in the shuttle lab, but the implementation of these experiments was much delayed, to May, 1991, as a result of the shuttle accident which occured in January, 1986. Nevertheless, work is proceeding smoothly on the development of experimentation hardware and the training of three scientists (PS's), one of whom will actually fly on the shuttle.

(2) Experiment Module for Attachment to Space Station (JEM)

In January, 1984, President Reagan proposed a space station project in which there would be international cooperation. Japan is to participate in this project with the development of the experimental module (JEM). The

space station proper will be a permanent, expandable, manned facility constructed in a low-altitude earth orbit. The station will be used in combination with a platform and orbiting work machinery to perform space experiments and astronomical and earth observations, and to serve as a supply and repair base. The JEM will be attached to the space station proper (100 m overall), and provide an environment for various space experiments. Actual development work is to begin in 1987 to meet a scheduled launch date in fiscal 1994.

(3) Space Experiments, Observations, Free Flyers

The SFU is a reusable satellite that flies in a low orbit. It is used for a number of purposes, including space experiments and astronomical and earth observations. The Science & Technology Agency, Ministry of Education, and MITI are to begin joint developmental work on this vehicle in 1987 in preparation for launch aboard an H-II rocket in fiscal 1992. The Science & Technology Agency and NASDA are to carry both this satellite and the JEM exposure module into orbit and test the reliability of the systems in space.

6. Space Plane

The development of a vehicle for making repeated round trips into space is essential for the practical utilization of space as we move into the space station era. The U.S. space shuttle is currently the only vehicle which can do this, but new space plane projects are being promoted which should make round-trip space transport and hypersonic transport feasible. These projects include the New Orient Express in the United States, the HOTOL project in the United Kingdom, and the ESA's HERMES project.

Basic research has been underway in Japan for some time too, at NASDA and the National Aerospace Laboratory, and more intensive research is to begin in fiscal 1987. In view of the situation, the Science & Technology Agency established the "Space Plane Study Group" (headed by Shigeo Kobayashi, Tokyo University professor) in its Research & Development Bureau for the purpose of clarifying the position of the space plane in Japan, identifying the tasks that must be addressed in order to proceed with this research and development, and conducting studies on Japan's long-range promotional policies from an international perspective. The group began work in December, 1986. A space plane bearing the rising sun of Japan should be flying by the late 1990's.

New Big-Rocket Era

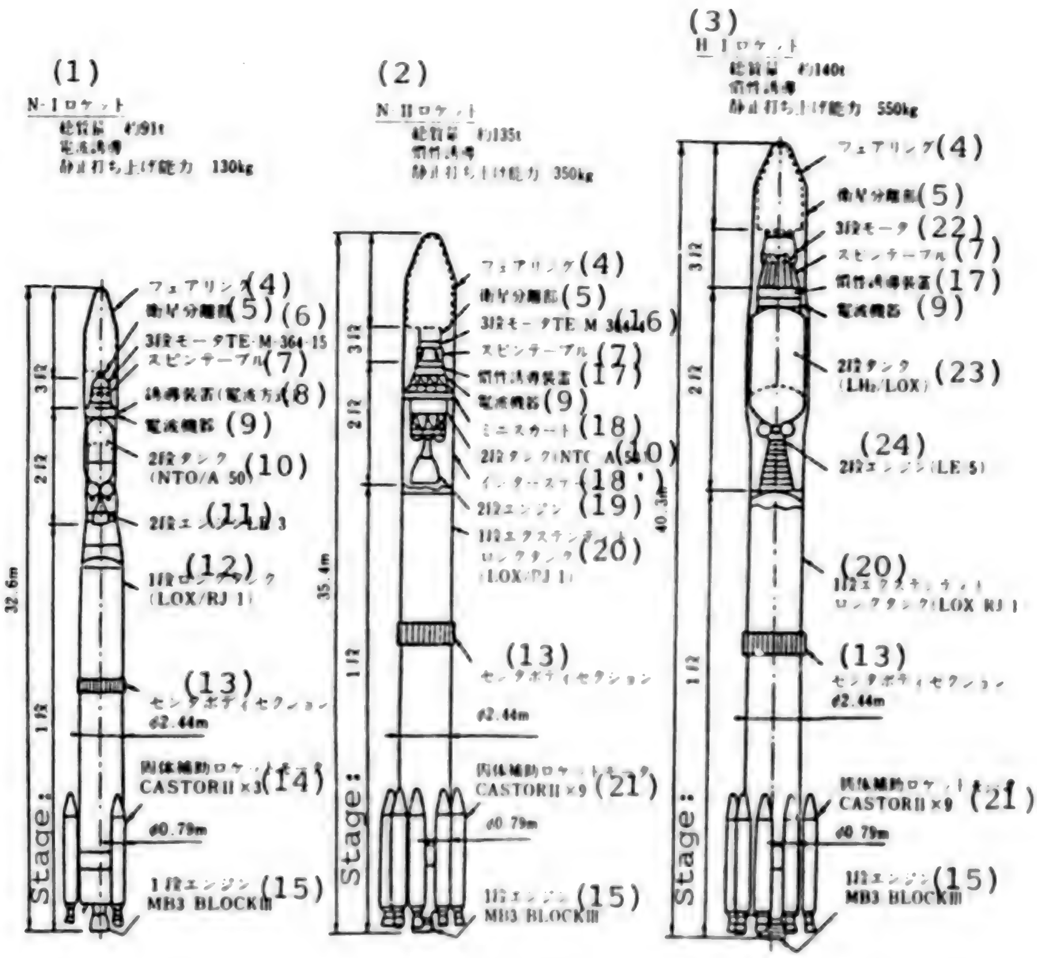
Tokyo PUROMETEUSE in Japanese Jan 87 pp 42 - 52

[Article by Rocket Development Center, National Space Development Agency]

[Text] 1. From N-I to H-I

Since the maiden launch of the first model of the N-I practical artificial satellite orbiting rocket in 1975, the N-I has launched seven artificial satellites, including technology-testing, ionosphere observing, and experimental stationary communications satellites. Use of the N-I was discontinued in 1982. The first of the presently operational N-II rockets was launched in 1981. The N-II has now launched seven satellites, including

Figure 1 N-1, N-II, and H-I Rockets



Key:
1. <u>N-I Rocket</u>
   Total mass: approx 91 tons
   Radio controlled
   Geostationary launch payload: 130 kg
2. <u>N-II Rocket</u>
   Total mass: approx 135 tons
   Inertial guidance
   Geostationary launch payload: 350 kg
3. <u>H-I Rocket</u>
   Total mass: approx 140 tons
   Inertial guidance
   Geostationary launch payload: 550 kg
4. Fairing
5. Satellite separation unit
6. Third-stage motor TE-M-364-15
7. Spin table
8. Guidance system (radio controlled)
9. Radio equipment
10. Second-stage tank (NTO/A-50)
11. Second-stage engine LE-3
12. First-stage long tank (LOX/RJ-1)
13. Center body section
14. Solid booster rocket motors, CASTOR II x 3
15. First-stage engine, MB3-BLOCK III
16. Third-stage motor TE-M-364-4
17. Inertial guidance system
18. Miniskirt
18'. Interstage
19. Second-stage engine
20. First-stage extended long tank (LOX/RJ-1)
21. Solid booster rocket motors, CASTOR II x 9
22. Third-stage motor
23. Second-stage tank (LH_2/LOX)
24. Second-stage engine (LE-5)

stationary meteorological, communications, and broadcast satellites. The only remaining task for the N-II rocket is the launch of Marine Observation Satellite No. 1 (MOS-1) in January, 1987. The N-I and N-II rockets were developed using technology borrowed from the U.S Delta rocket. The payload for launch into geostationary orbit is approximately 130 kg for the N-I rocket, and approximately 350 kg for the N-II rocket. The configurations of these rockets are diagrammed in Figure 1.

The N-II rocket has maintained an extremely high launch success rate. As satellites take on more and more functions, however, more launch power is desired in rockets, and the 350-kg payload of the N-II rocket has now become inadequate. The H-I rocket, which can orbit a payload of 550 kg, was developed by taking the highly reliable N-II rocket and enhancing the

performance of its upper-stage rockets. Besides the enhanced launch performance, the H-I rocket has another important mission, namely the transition to indigenous Japanese technology in the major areas of rocket technology, where dependence on borrowed technology from the United States has been very strong. It is very difficult, however, to switch entirely away from borrowed technology to indigenous technology, so the first stage of the N-II rocket, which is a big development item, will continue to be used unmodified, but the upper-stage rockets and guidance systems will be developed in Japan. There are three main technologies which are to be developed domestically for the H-I rocket, namely a second-stage rocket using liquid oxygen and liquid hydrogen as propellants, an inertial guidance system, and a third-stage solid-fuel rocket. The development of the liquid-oxygen/liquid-hydrogen propulsion system for the second-stage will provide enhanced launch potential and the realization of the development of home-grown rocket technology. On August 30, 1986, an experimental two-stage H-I rocket was launched from the Tanegashima Space Center, accurately orbiting a geodetic experiment satellite ("Ajisai"), a device made by the National Aerospace Laboratory to test a magnetic-bearing flywheel, and an amateur radio satellite ("Fuji"). This success demonstrated the viability of the performance and functions of the newly developed second-stage rocket and intertial guidance system. Moreover, this flight accelerated the development of the H-II rocket because of the normal operation of the reignition functions in the second-stage liquid-oxygen/liquid hydrogen system, technology that is considered very difficult to perfect. What is meant here by reignition is the technology of refiring the second-stage rocket motor--after it has completed its initial burn and the vehicle has begun inertial flight--in order to insert the satellite into the targeted orbit. This has been successfully performed only by the United States and China with liquid-oxygen/liquid-hydrogen rockets. Reignition facilitates both rocket system simplification and launch diversification. Next on the schedule is the launch of a three-stage experimental H-I vehicle, in summer, 1987, to insert the 550-kg Experimental Technology Satellite Model V (ETS-V) into geostationary orbit. After that, the H-I rocket will enter the transport stage, inserting communications, broadcast, and meteorological satellites into geostationary orbit, and launching earth resource satellites into sun-synchronous orbits. The configuration of the H-I vehicle is depicted in Figure 1 and its main specifications are given in Table 1. In Figure 2 is depicted the LE-5 engine, which uses liquid oxygen and liquid hydrogen as propellants and which was developed for use in the second stage of the H-I rocket. The artificial satellite launch plans for the N-I, N-II, and H-I vehicles are given in Table 2. The launch costs currently associated with the N-II and H-I rockets are, unfortunately, quite a bit higher than those for European and American rockets. This is due to the early perfection of geostationary satellite launch technology for these rockets, and to Japan's intensive efforts to develop its own technology. Hence cost reductions must await the next-generation launch vehicle, i.e. the H-II rocket, which is being developed with the objective of placing 2-ton payloads into geostationary orbit at costs which are equal to or less than those of Europe and America. In developing the H-II rocket, maximum use is being made of technology developed with the H-I rocket and with the M rocket developed by

Table 1 H-I Rocket Specifications

	(1) 全 段
全(2)長(m)	40.30
外(3)径(m)	(6) 2.49(第2段ロケット)
全備重量(t)(4)	(7) 139.3(人工衛星の重量は含まない)
誘導方式(5)	(8) 慣性誘導方式

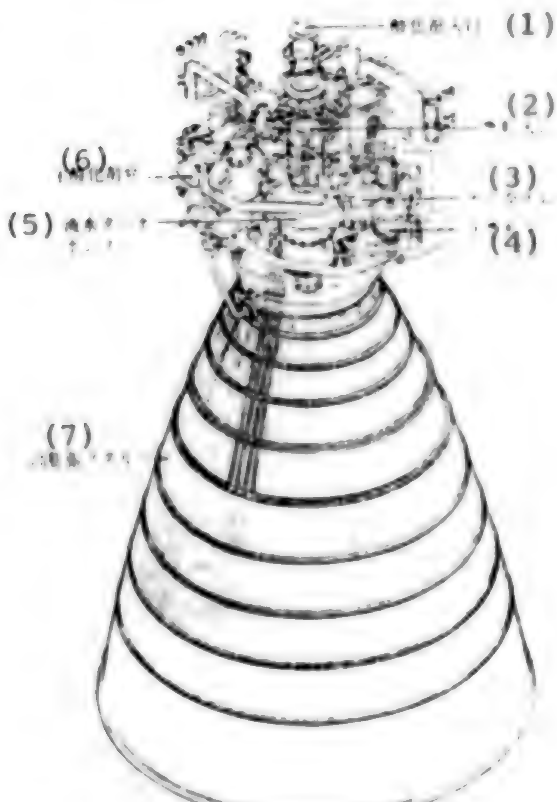
	(9) 各 段				
	(10) 第 1 段	(11) 固体補助ロケット	(12) 第 2 段	(13) 第 3 段	(14) 衛星フェアリング
(15) 全 長(m)	22.44	7.25	10.32	(28) [illegible].34 固体モータ長 2.04	7.91
外(16)径(m)	2.44	0.79	2.49	1.34	2.44
各段重量(t)(17)	85.8*1	40.3(9本分)(29)	10.5	2.[illegible]*2	0.6
推進薬重量(t)(18)	81.4	33.8(9本分)*5	8.7	1.8	
(19) 平均推力(t)	メインエンジン(32) 77.1*3 バーニアエンジン(33) 0.9(2基分)	135.0(6本分)(30) 67.5(3本分)(31) *3 *5	10.5*4	7.9*4	
(20) 燃焼時間(s)	メインエンジン(34) 約270 バーニアエンジン(35) 約276	39	(38) 約370	68	
(21) 推進薬種類	(36) 液化酸素/RJ-1	(37) ポリブタジエン系コンポジット固体推進薬	(39) 液化酸素/液化水素	(37) ポリブタジエン系コンポジット固体推進薬	
(22) 推進薬供給方式	(40) ターボポンプ		(40) ターボポンプ		
(23) 比推力(s)	メインエンジン(41) 253*3 バーニアエンジン(42) 209*3	235*3	449.7*4	291.7*4	
(25) 姿勢制御 (24) ピッチ・ヨー	(43) ジンバル		(44) ジンバル(動力飛行中) (45) ガスジェット(慣性飛行中)		
(25) 姿勢制御 ロ(26)ール	(46) バーニアエンジン		(47) ガスジェット		
(27) 搭載電子装置	(48) (1)テレメータ送信装置 290MHz帯 PCM/PM (49) (2)指令破壊受信装置 2.6GHz帯 トーン変調		(50) (1)レーダトランスポンダ 5GHz帯(2台) (51) (2)テレメータ送信装置 2.2GHz帯 PCM/PM (53) (3)指令破壊受信装置 2.6GHz帯(2台) トーン変調	(1)テレメータ送信装置 290MHz帯 PAM/FM/PM (52)	

(54) *1 アダプタセクションを含む。
*2 スピンテーブルを含む。
*3 海面上ノミナル値
*4 真空中ノミナル値
*5 打上げ時は6本のみ燃焼。6本の燃焼終了後残り3本を燃焼させる。

Key to Table 1:
1. All stages
2. Overall length (m)
3. Outer diameter (m)
4. Gross service weight (t)
5. Guidance system
6. 2.49 (second-stage rocket)
7. 139.3 (not including weight of artificial satellite)
8. Inertial guidance system
9. Each stage
10. First stage
11. Solid booster rockets
12. Second stage
13. Third stage
14. Satellite fairing
15. Overall length (m)
16. Outer diameter (m)
17. Weight of each stage (t)
18. Weight of propellant (t)
19. Average thrust (t)
20. Burn time (s)
21. Type of propellant
22. Method of supplying propellant
23. Specific impulse (s)
24. Pitch / yaw
25. Attitude control
26. Roll
27. Electronic gear carried
28. Solid motor length
29. 40.3 (for 9 motors)
30. 135.0 (for 6 motors)
31. 67.5 (for 3 motors)
32. Main engine, 77.1 *3
33. Vernier engines, 0.9 (for two units)
34. Main engine, approx 270
35. Vernier engine(s), approx 276
36. Liquid oxygen/RJ-1
37. Polybutadiene-based components, solid propellant
38. Approximately 370
39. Liquid oxygen/liquid hydrogen
40. Turbopump
41. Main engine, 253 *3
42. Vernier engines, 209 *3
43. Gimbals
44. Gimbals (during powered flight)
45. Gas jets (during inertial flight)
46. Vernier engine(s)
47. Gas jets
48. (1) Telemetric transmission equipment, 290 MHz band, PCM/PM
49. (2) Command destruct receiving unit, 2.6 GHz band, tone modulated

50. (1) Radar transponder, 5 GHz band (2 units)
51. (2) Telemetric transmission equipment, 2.2 GHz band, PCM/PM
52. (1) Telemetric transmission equipment, 290 MHz band, PAM/FM/PM
53. (3) Command destruct receiving unit, 2.6 GHz band (2 units), tone modulated
54. Notes:
   *1 Including adapter section
   *2 Including spin table
   *3 At sea level / tower value
   *4 In vacuum / tower value
   *5 Only six motors are burned during launch. The remaining three are burned after the first six have finished burning.

Figure 2 H-I Second-Stage Engine



Key:
1. Oxidation agent intake
2. Fuel intake
3. Gas generator
4. Main fuel valve

5. Liquid hydrogen turbopump
6. Main oxidation agent valve
7. High-expansion nozzle

Table 2 Satellite Launch Schedule

Key:
1. N-I Project
2. N-II Project
3. H-I Project
4. (Two-stage configuration)
5. (Three-stage configuration)
6. (black arrow) Already launched
7. (white arrow) Year of launch decided

Satellite Names & Nomenclature

ETS-I	Experimental Technology Satellite I (H = 1000 km, circular)
ISS	Ionosphere Surveying Satellite (H = 1000 km, circular)
ETS-II	Experimental Technology Satellite II (stationary)
ECS-b	Experimental Geostationary Communications Satellite (failed to reach stationary orbit)
ETS-III	Experimental Technology Satellite III (H = 1000 km, circular)
EGS	Experimental Geodetic Satellite (H = 1500 km, circular)
ETS-IV	Experimental Technology Satellite IV (stationary transfer)
GMS-2	Geostationary Meteorological Satellite No. 2 (stationary)
CS-2a,2b	Communications Satellite No. 2 (stationary)
BS-2a,2b	Broadcast Satellite No. 2 (stationary)
GMS-3,4	Geostationary Meteorological Satellites No. 3, 4 (stationary)
MOS-1	Marine Observation Satellite (H = 909 km, circular, sun-synch)
ETS-V	Experimental Technology Satellite V (stationary)
CS-3a,b	Communications Satellite No. 3 (stationary)

BS-3a,b   Broadcast Satellite No. 3 (stationary)
ERS-1   Earth Resource Satellite (sun-synchronous)

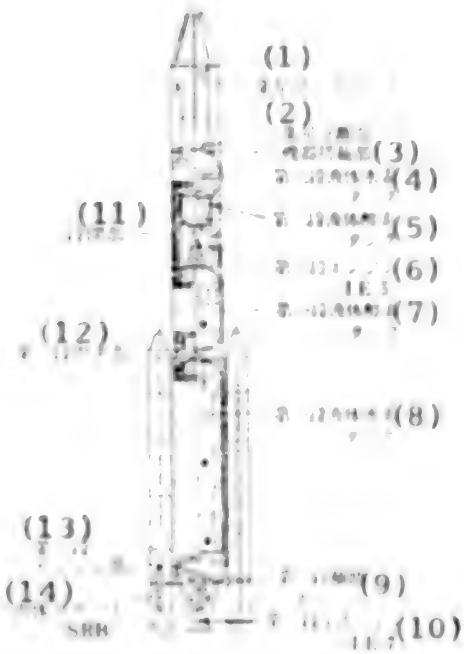
TF....Test flight   Stationary....geostationary orbit
H.....Altitude   Circular......circular orbit

the National Aerospace Laboratory. The goal is to launch a prototype vehicle in the winter of 1992.

2. New-Generation Rocket H-II

The objectives in developing the H-II rocket may be broadly grouped into three areas, as follows. (1) Cope with Japanese satellite demand during the 1990's by providing the capability to launch two-ton class satellites into stationary earth orbit, and to simultaneously launch multiple one-ton class satellites into stationary orbit. (2) Develop all systems with indigenous technology. Thus far, Japan has had to borrow rocket technology from the United States for its practical satellite launching rockets. It was by this technological borrowing that Japan has perfected its satellite launching technology to the current level, but it is also true that this approach has brought with it restrictions imposed by the United States. Before Japan can launch a satellite for some third-party nation, it must first confer with the United States and obtain the latter's approval. The

Figure 3   H-II Rocket



Key:
1. Satellite fairing
2. Satellite separation unit
3. Instrumentation
4. Second-stage liquid hydrogen tank
5. Second-stage liquid oxygen tank
6. Second-stage engine (LE-5)
7. First-stage liquid oxygen tank
8. First-stage liquid hydrogen tank
9. First-stage booster engine
10. First-stage main engine (LE-7)
11. Inter-stage unit
12. First-stage central unit
13. First-stage engine unit
14. Solid rocket (SRB)

Table 3 H-II Specifications

(1)		Specification		
(2)		48m		
(3)		4m		
(4)		258t		
		(15) 第一段	(16) 固体ロケット	(17) 第二段
(5)		(18) [illegible]	(19) [illegible]	(18) [illegible]
(6)		85t	(20) 118t (2本分)	13t
(7)		(21) 93t (海面上)	(22) 320t (2本分・海面上)	(23) 10.5t (真空中)
(8)		315.8s	95s	(24) 535s (再着火機能)
(9)		(25) 449s (真空中)	(26) 271s (真空中)	(27) 449.7s (真空中)
(10)		97t	(28) 140.5t (真空中)	15.7t
(11) フェアリング	(12)	(29) 4.1m (外径) × 12m		
	(13)	(30) 約3.7mφ × 10mL		
(14)		(31) ストラップダウン慣性誘導システム		

Key:
1. Item
2. Overall length
3. Diameter
4. Liftoff weight
5. Propellants
6. Propellant weight
7. Thrust
8. Burn time
9. Specific impulse
10. Fully-serviced weight
11. Satellite fairing
12. Diameter x overall length
13. Satellite accommodation area

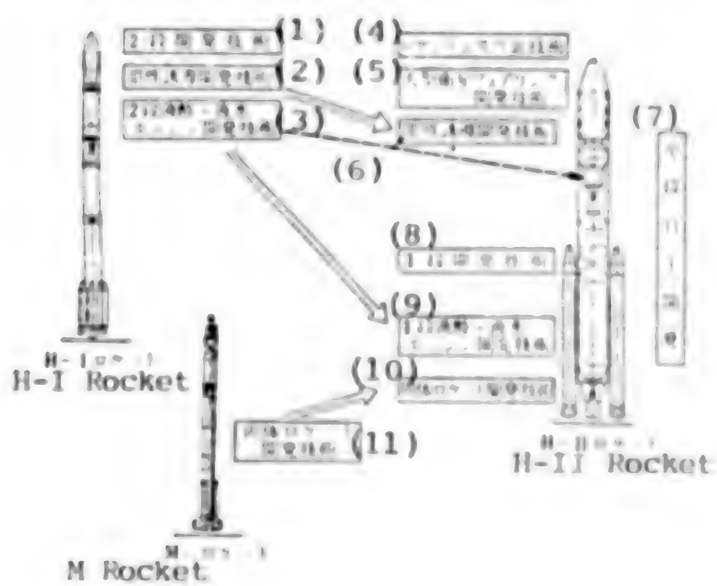
14. Guidance system
15. First stage
16. Solid rockets
17. Second stage
18. Liquid oxygen/liquid hydrogen
19. Solid propellant
20. 118 t (with 2 motors)
21. 93 t (at sea level)
22. 320 t (with 2 motors, at sea level)
23. 10.5 t (in vacuum)
24. 535 s (supporting hydrogen reignition function)
25. 449 s (in vacuum)
26. 271 s (in vacuum)
27. 449.7 s (in vacuum)
28. 140.5 t (in vacuum)
29. 4.1 m (outer diameter) x 12 m
30. Approx 3.7 m phi x 10 mL
31. Strap-down inertial guidance system

H-I launch vehicle, which uses a first-stage rocket obtained from the United States, is no exception to this rule. Thus an important objective of the H-II rocket is the ability to launch satellites without these restrictions. (3) The third objective is to perfect the H-II into a highly reliable rocket that rarely fails on launch and that is as cost effective as the world-class rockets of the 1990's are expected to be.

Even though the development of this new rocket requires all of these problems and tasks to be dealt with, the total development costs are being kept quite low, as judged by international norms. That this can be done is due to the simple configuration of the H-II vehicle, and to the maximal use being made of domestic technology developed with the H-I and M rockets. The H-II rocket is a two-stage vehicle having an overall length of 47 m, a diameter of 4 m, and a gross weight of approximately 260 tons. The external configuration is depicted in Figure 3. The main specifications are given in Table 3. The first-stage carries a single LE-7 liquid-oxygen/liquid-hydrogen engine which develops a thrust (at sea level) of approximately 93 tons. The operating time for the first-stage engine is approximately 320 seconds. Liquid oxygen and liquid hydrogen were also selected as the propellants for the first stage because of the experience gained with the H-I rocket and because of the high performance of such systems. The first stage is being configured with a single rocket engine for several reasons. The timeframe just for developing the LE-7 engine is very severe, and adopting a cluster configuration would require more time to develop, involve too many technical problems which would have to be solved, and involve too much risk if adopted for the H-II vehicle. Hence, in order to increase the first-stage thrust and attain adequate launch capability, two solid rocket motors (SRB's) are mounted on the first stage. The adoption of these solid rockets makes it possible to keep the size of the first-stage rocket relatively compact, and to keep development and fabrication costs low. In developing these solid rockets, technology is being used

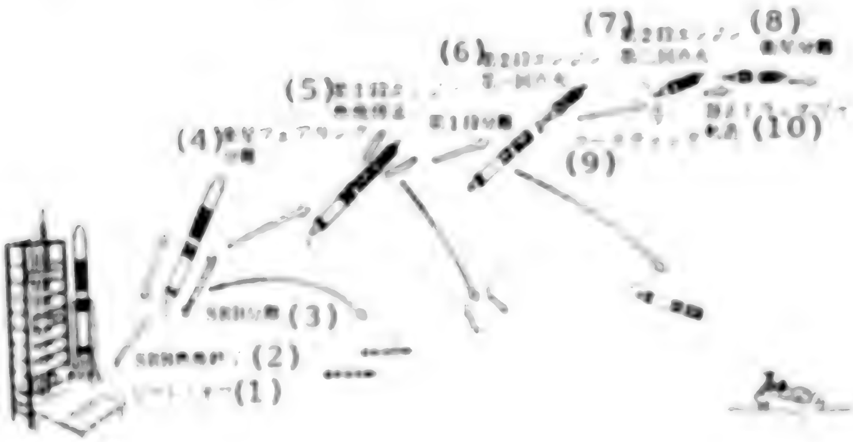
from the M rocket developed by the Ministry of Education's National Aerospace Laboratory. For the second stage, the second stage of the H-I rocket is used with almost no modification. The quantities of liquid oxygen and liquid hydrogen are increased roughly 50 percent, however, so the liquid oxygen tank is a lengthened version of the tank used on the H-I rocket, and the liquid hydrogen tank is a shortened version of the H-II's first-stage tank. This approach makes it possible to keep development costs from escalating. In launching a stationary satellite, the vehicle is first inserted into a circular "parking" orbit at an altitude of approximately 200 km with the first burn of the second-stage rocket. Then, over the equator, the LE-5 engine is reignited and the satellite is inserted into a stationary transfer orbit. The LE-5 engine's reignition capability makes it possible to keep the configuration simple, using two stages instead of three, thereby reducing launch costs. The satellite fairing has a diameter of 4.1 m and a length of 12 m, which is adequate to accommodate a 2-ton class geostationary satellite. Two 1-ton class geostationary satellites can be accommodated with the use of special adapters. A study is also being done on the feasibility of expanding the fairing diameter to 5 m (the same as the space shuttle) to accommodate large, low-orbiting satellites. Guidance is provided by the inertial guidance system of the H-I rocket, except that the high-performance, highly reliable strap-down method, which employs ring laser gyros, was adopted for the inertial sensing units. This modification was made in the interest of enhanced performance and lower cost. The adoption of the strap-down method was also considered when development was

Figure 4 Course of Technological Development



Key:
1. Second-stage development technology
2. Inertial guidance development technology
3. Second-stage liquid-oxygen/liquid-hydrogen engine development technology
4. Rocket system technology
5. Large satellite fairing development technology
6. Inertial guidance development technology
7. Indigenous development of all stages
8. First-stage development technology
9. First-stage liquid-oxygen/liquid-hydrogen engine development technology
10. Solid rocket development technology
11. Solid rocket development technology

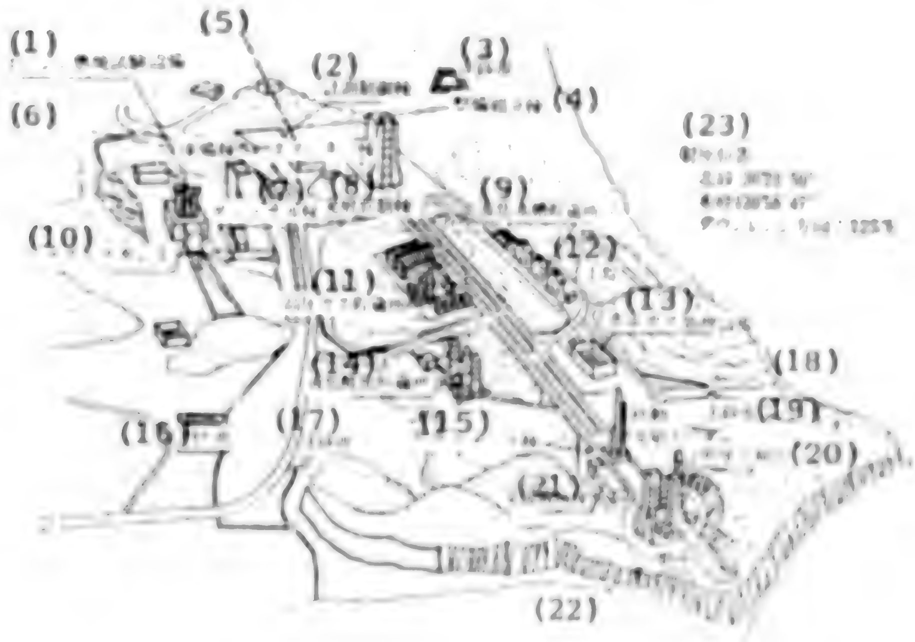
Figure 5 Flight Sequence



Key:
1. Liftoff
2. SRB burn complete
3. SRB separation
4. Satellite fairing separation
5. First-stage engine burn terminates
6. Second-stage engine's first ignition
7. Second-stage engine's second ignition
8. Satellite separation
9. Coasting
10. Stationary transfer orbit

started on the H-I rocket, but high-input-angle gyros had not yet been developed for the strap-down method, and the stable platform method was adopted. The model configuration of the H-II rocket was decided by the Space Activities Commission in July, 1984, and development work began in April, 1986. This work is being conducted according to the development itinerary given in Table 4. The first prototype is scheduled to lift off from a new launch complex at the Tanegashima Space Center in January or February, 1992. A second prototype is to launch Experimental Technology Satellite VI (ETS-VI) in August or September of the same year. The new launch complex for the H-II rocket is located about 0.6 km northeast of the launch complex for the N-II and H-I rockets. Construction work is being conducted as shown in Figure 6. The rockets and ranges are planned to facilitate launching two H-II rockets in the summer season and two in the winter season. This would allow the launch of four vehicles a year under the current restrictions.

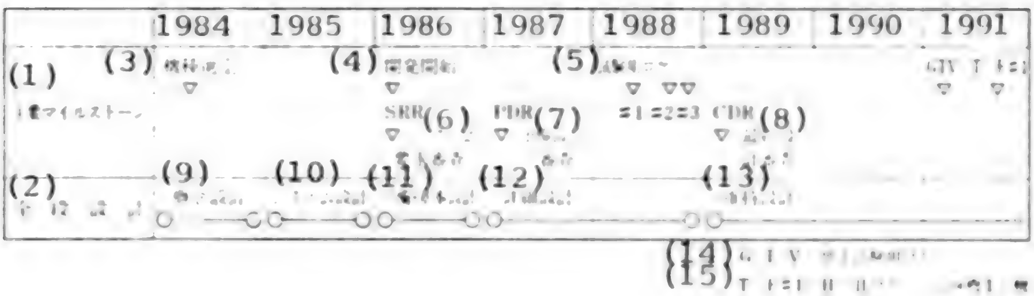
Figure 6 H-II Rocket Launch Complex Layout



Key:
1. Engine burn test facility
2. Measurement control building
3. Sedimentation basin
4. Servicing & equipment building
5. Power facility
6. Preparation building

7. Terminal building
8. Launch control building
9. Liquid hydrogen storage facility
10. Test stand
11. High-pressure gas storage facility
12. Levee
13. Hydrogen gas processing facility
14. Liquid oxygen generation and storage facility
15. Alignment building
16. Sedimentation basin
17. Sedimentation basin
18. Movable launch pad
19. Sedimentation basin
20. Launch site inspection tower
21. Support equipment building
22. Launch site

Table 4 Development Schedule

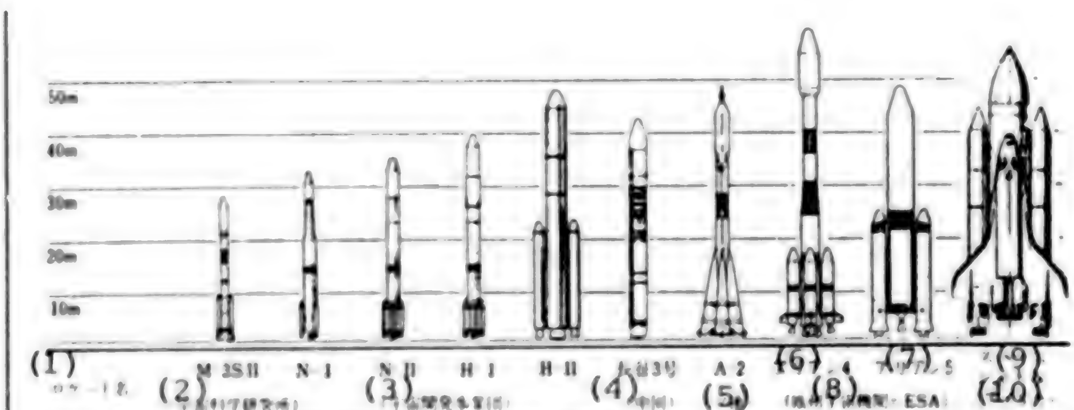


Key:
1. Main milestones
2. Design of all stages
3. Model configuration selection
4. Development begins
5. Prototype rockets
6. SRR (system request review)
7. PDR (preliminary design review)
8. CDR (completed design review)
9. Concepts design
10. Systems design
11. Preliminary/basic design
12. Detailed design
13. Maintenance design
14. GTV: ground test vehicle
15. T/F #1: H-II prototype #1

3. H-II Rocket Utilization, Upgrade Potential

The projected cost of the H-II rocket is equivalent to that of the Arienne IV rocket, which has about the same launch capability. When the configuration of the H-II was determined in 1984, the dollar was exchanging for 240 yen, and the cost of the H-II vehicle was less than the launch fees charged by Europe and the United States. The exchange rate became 160 yen to the dollar in 1986, but the fees charged for Arienne launch rose due to the space shuttle and Arienne rocket failures, so that these are now roughly equivalent to the H-II's cost. The targeted costs for the H-II rocket are based on two vehicles per year. If the number of launches increases, the cost per launch will naturally come down. The H-II, moreover, offers great potential for further development and enhancement, and by augmenting the technologies developed for the H-II with a few new elements, it will be possible to increase its launch capability by from 1.5 to 3 times. As the launch capability is raised, the cost per unit payload weight can be reduced by 30 - 50 percent. Enhanced models of the H-II rocket are illustrated in Figure 8. If the launch capability is at international levels, and there is no inferiority in terms of price or reliability, inroads into the world market will be made automatically. The vehicle can then be used for launching all kinds of artificial satellites, and will not be limited to launching geostationary satellites. Let us now examine various satellite launches in which the H-II vehicle can be used.

Figure 8 Japanese Rockets Compared With Typical Foreign Rockets

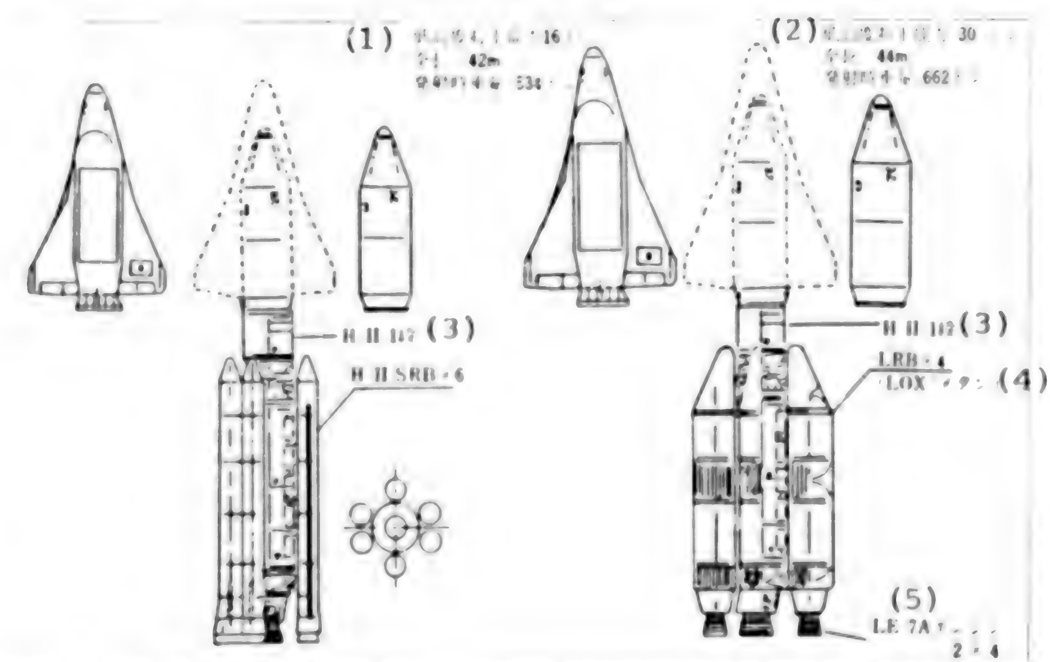


(11)	61	90	135	140	250	191	310	460	500	2.041
(12) kg	670	1.200	2.000	3.000	9.000	5.000	—	8.000	15.000	29.500
(13) kg	—	130	350	550	2.000	700	—	2.200	4.000	2.400 (14)

Key:
1. Rocket name
2. (National Aerospace Laboratory)
3. (National Space Development Agency (NASDA))
4. Changzheng III (China)
5. (Soviet Union)
6. Arienne 4
7. Arienne 5
8. (European Space Agency = ESA)
9. Space shuttle
10. (United States)
11. Gross weight (t)
12. Low-orbit launch capability (kg)
13. Geostationary-orbit launch capability (kg)
14. (Using upper-stage rocket)

The H-II vehicle has the capability of placing a 2-ton class satellite into geostationary orbit. Thus, with LE-5 enhancements, the H-II has the power to launch satellites up to and including the INTELSAT VI class. The rocket can also simultaneously launch two 1-ton class satellites, or three 600-kg class satellites, making it very launch-cost effective. In the 2-ton stationary class there are, following the ETS-VI, communications, broadcast, and data-relay tracking-control satellites to be launched, and 1-ton class commercial communications satellites and weather satellites will continue to be orbited. Should a demand for launching geostationary satellites weighing 4 tons or more develop, this can be met by enhanced versions of the H-II vehicle.

Figure 9 Examples of Enhanced H-II Vehicles



Key:
1. Low-altitude launch capability: 16 tons
   Overall length: 42 m
   Launch weight: 534 tons
2. Low-altitude launch capability: 30 tons
   Overall length: 44 m
   Launch weight: 662 tons
3. H-II second stage
4. (LOX/methane)
5. LE-7A engine 2 x 4

Besides the geostationary satellites, other useful and practical satellites include the earth observation satellites that are launched into a sun-synchronous north-south orbit at an altitude of 1000 km or so. Typical of these are the resource exploration LANDSAT and SPOT satellites. In January, 1987, Japan is to launch its Marine Observation Satellite (MOS-I), and plans subsequently to launch the Earth Resource Satellite (ERS) with the H-I rocket. The H-II vehicle can launch a 5-ton class satellite, twice the weight of the LANDSAT IV, and cost efficiencies can be realized by simultaneously launching two LANDSAT class satellites. The vehicle can also launch a platform carrying various observation systems.

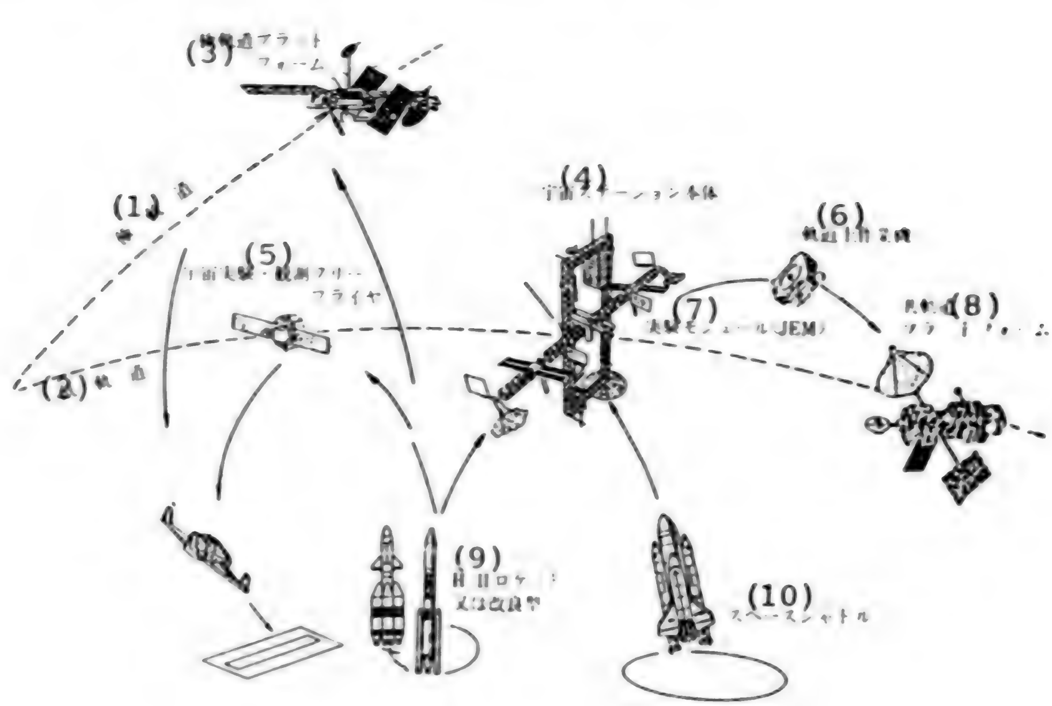
Japan has not been able to carry out serious exploration of the moon or planets, which are more distant from earth, but the H-II rocket has the capability of sending a 3-ton package to the moon, a 2-ton package to Venus or Mars, and an exploratory vehicle of considerable weight even to the outer planets. Using enhanced versions of the H-II rocket, not only can exploratory devices be sent to the planets, but even the recovery of samples from the planets is not beyond the realm of possibility.

The 400-km altitude low-orbit launch capability will become roughly 10 tons, and materials could be supplied to a space station at a lower transport cost than with the space shuttle. The vehicle will also be used to launch free flyers (unmanned experimental vehicles operated from low orbit) and platforms.

The National Aerospace Laboratory, NASDA, and MITI are now planning to launch a space flyer unit (SFU) with the H-II rocket in 1993.

For the time being, the H-II vehicle will be used only for launches, and recoveries will be made using the space shuttle. The co-orbital platform now being planned by NASDA is also being developed with a view to launching it with the H-II rocket. Studies are also moving ahead on using the H-II to launch replenishment shipments for the Japanese Experimental Module (JEM) that will attach to NASA's space station. Since two H-II launches a year would not be sufficient in view of the predicted annual replenishment quantities needed for the JEM, and in the interest of lowering transport costs, the utilization of enhanced versions of the H-II vehicle is also being studied.

Figure 10 Utilization of Low-Altitude Orbits



Key:

1. Polar orbit
2. Low orbit
3. Polar-orbital platform
4. Space station proper
5. Space experiment/observation free flyers
6. Orbital operation machine
7. Experimentation module (JEM)
8. Co-orbital platform
9. H-II rocket or enhanced version
10. Space shuttle

Research is also being done with the goal of launching a round-trip space transport system by around 1995. This system would be launched by carrying the round-trip space vehicle atop the H-II rocket or one of its enhanced versions, and would travel to and from the JEM, Japan's own space station, or a space factory. The size of the round-trip space vehicle will be determined according to projections of future demand for material and personnel transport, and transport costs. With the H-II, it is possible to launch a winged craft weighing about 10 tons. With an enhanced H-II, this payload could be raised to between 16 and 30 tons.

As discussed above, considerable demand is predicted for the H-II rocket, and it is very likely that four or more launches a year will be necessary. If the technology developed for the H-II rocket is extended, it should be possible to realize large increases in launch capability and to reduce per-unit-weight launch costs. This will no doubt promote the dawn of the space industry age. The H-II rocket and its enhanced versions should also play a role in realizing a completely reusable space transport system after the turn of the century. Even if such systems are realized, expendable rockets will probably continue to be used.

Japanese Utility Satellites Familiarized

Tokyo PUROMETEUSE in Japanese Jan 87 pp 53 - 62

[Article by Artificial Satellite Development Center, National Space Development Agency]

[Text] Prolog

Where do you suppose you get connected to if you directly dial area code 04998? Well, this connects you to Chichijima, Ogasawara Mura, Tokyo, and it is actually a commercial telephone line that uses Japan's utility communications satellite "Sakura 2." Chichijima is in the Tokyo postal zone, but it is actually a small island in the Pacific Ocean, some 1000 km from Tokyo Bay.

Until a few years ago, it was not this easy to call Chichijima. You first had to dial the operator and make a request. Then, when you were finally connected after a considerable wait, the static on the shortwave line often made it very difficult to carry on a conversation. Some of you may remember such experiences. Thanks to Sakura 2, you can now dial Chichijima direct. The voice quality compares to calling within the city, and the conversational delay compares to that experienced when making an international call. We are now going to make a brief magazine visit to Chichijima.

You cannot actually travel to Chichijima in quite the smart manner as you can call the island via communications satellite. It takes about 28 hours aboard the appropriately dubbed Ogasawara Maru, a 3000-ton vessel that leaves Tokyo Harbor once a week. After World War II, the island was administrated by the United States for a while, a fact which might be guessed from some of the names one finds in the villages. The semitropical geography and beautiful sea combine to make the place very exotic.

Relaxing in your hotel room, you turn on the TV to an NHK station and find the reception to be beautifully clear and noise-free. After watching it for a while, however, you begin to feel that the programs are a little different from the ones you are used to. You try changing channels and finally realize what is going on. Here on Chichijima you can only get the NHK satellite broadcast sent out from the Yuri 2.

The latest cultural benefits are usually experienced first in the big cities, but we may expect the benefits provided by utility satellites to reach both the big cities and the outlying regions at the same time and with the same quality. Such far-reaching capabilities and simultaneity are among the special characteristics of utility satellites.

Present Status of Utility Satellites

With much reluctance, let us now shift our attention away from Chichijima and briefly consider what sort of things come under the heading of utility satellite. Please look at Table 1. This is a systematic presentation of the fields of artificial satellite utilization that generally pertain to utility satellites. The satellites noted within parentheses in Table 1 have either already been implemented in Japan, or are planned. Some kind of implementation or planning has been done in all the categories under (1) Communications & Broadcasting and (2) Earth Observation. In the field of navigational aids, so-called worldwide positioning systems such as NNSS (Navy Navigation Satellite System) and GPS (Global Positioning System) are now operational, but there is still no specific plan for the local region of Japan.

Table 1 Utility Satellite Fields

```
(1) Communications & Broadcasting
                     !
                     +--Relay Communications
                     !          !
                     !          +--Fixed Communications...(Communications
                     !          !   Satellite "Sakura")
                     !          +--Mobile Communications...(Experimental
                     !              Technology Satellite V)
                     !                Communications to aircraft, ships,
                     !                automobiles, etc.
                     !
                     +--Direct Communications (Broadcast Satellite "Yuri")

(2) Earth Observation
             !
             +--Weather Observation...(Meteorological Observ Sat "Himawari")
             +--Ocean Observation.....(Marine Observation Satellite)
             +--Land Observation....(Earth Resource Satellite)
                                    (Geodetic Experiment Satellite "Ajisai")

(3) Navigational Aids
             !
             +--Satellite systems to provide ships and aircraft, etc., with
                  position information
```

Let us next discuss Japanese utility satellites in greater detail, field by field. For reference, the artificial satellites are also grouped according to launch vehicle in Table 2.

Table 2 Artificial Satellite Development Projects (as of October, 1986)

N-I PROJECT

Satellite Type: Experimental Technology Satellite I (ETS-I), "Kiku"

Major Objectives: First test satellite launched by NASDA. Demonstrated rocket launching technology, acquired knowledge on tracking and controlling satellites, conducted antenna extending experiment and measured satellite environmental conditions.

Specifications: Weight: Approx 82.5 kg Shape: 26-surface unit having diameter of approx 80 cm

Launch Date, Launch Vehicle: September 9, 1975 N-I rocket

Comments: Operation terminated April 28, 1982

Satellite Type: Ionosphere Survey Sat (ISS) "Ume," (ISS-b) "Ume 2"

Major Objectives: Objectives were to conduct ionospheric observations and improve precision of forecasts for radio communications, but communications with ISS ceased 1 month after launch. Back-up ISS-b was therefore launched with same objectives.

Specifications: Weight: Approx 141 kg Shape: Cylindrical body, diameter approx 94 cm, height approx 82 cm

Launch Date, Launch Vehicle: (ISS) February 29, 1976 (ISS-b) February 16, 1978 N-I rocket

Comments: Operation terminated February 23, 1983 (ISS-b)

Satellite Type: Experimental Technol Satellite II (ETS-II) "Kiku 2"

Major Objectives: Gained knowledge on geostationary satellite launch, conducted attitude control function tests, conducted tests on functioning of on-board instruments. Japan's first geostationary satellite.

Specifications: Weight: Approx 130 kg Shape: Cylindrical body, diameter approx 140 cm, height approx 90 cm

Launch Date, Launch Vehicle: February 23, 1977 N-I rocket

Comments: Now being used toward end of useful lifespan

Satellite Type: Experimental Geostationary Communications Satellite (ECS) "Ayame" (ECS-b) "Ayame 2"

Major Objectives: Objectives were to perfect geostationary satellite launch technology, tracking and control technology, and attitude control technology, etc., and to conduct milliwave communications experiments using a stationary satellite, but communications with both the ECS and the subsequently launched back-up ECS-b ceased after the apogee motors were fired.

Specifications: Weight: Approx 130 kg Shape: Cylindrical body, diameter approx 140 cm, height approx 95 cm

Launch Date, Launch Vehicle: (ECS) February 6, 1979 (ECS-b) February 22, 1980 N-I rocket

Satellite Type: Experimental Technology Sat III (ETS-III) "Kiku 4"
Major Objectives: To demonstrate tri-axial control functions and solar-cell paddle deployment functions, test the functions of the on-board experimental instruments, and develop general technology for artificial satellites requiring large amounts of power.
Specifications: Weight: Approx 385 kg Shape: Box-shape having deployable solar-cell paddle
Launch Date, Launch Vehicle: September 3, 1982 N-I rocket
Comments: Operation terminated March 8, 1985

GMS, CS, BS PROJECTS

Satellite Type: Geostationary Meteorological Sat (GMS) "Himawari"
Major Objectives: Participating in Global Atmospheric Development Project (GARP) conducted by World Meteorological Organization and International Science Federation, conducted observations of cloud patterns by stationary satellite, thereby improving precision of weather forecasting and otherwise enhancing meteorological operations.
Specifications: Weight: Approx 303 kg Shape: Cylindrical body Diameter: Approx 220 cm
Launch Date, Launch Vehicle: July 14, 1977 Delta 2914 rocket (launched by United States)
Comments: Standing by in orbit

Satellite Type: Experimental Medium-Volume Geostationary Communications Satellite (CS) "Sakura"
Major Objectives: As a step toward launching large-capacity communications satellites, tested semi-milliwave communications with a satellite system and contributed to perfection of operation technology for satellite communications systems.
Specifications: Weight: Approx 350 kg Shape: Cylindrical body Diameter: Approx 220 cm
Launch Date, Launch Vehicle: December 15, 1977 Delta 2914 Rocket (launched by United States)
Comments: Operation terminated November 25, 1985

Satellite Type: Experimental Medium-Sized Broadcast Sat (BS) "Yuri"
Major Objectives: As a step toward launching large broadcast satellites, conducted video and audio transmissions using satellite systems and contributed to perfection of operation technology for broadcast satellite systems.
Specifications: Weight: Approx 350 kg Shape: Box-shape with deployable solar-cell paddle
Launch Date, Launch Vehicle: April 8, 1978 Delta 2914 rocket (launched by United States)
Comments: Control of satellite ended January 23, 1982

N-II PROJECT

Satellite Type: Experimental Technology Sat IV (ETS-IV) "Kiku 3"

Major Objectives: Demonstrated ability of N-II rocket to insert payload into transfer orbit, ascertained launch environment conditions, and gained knowledge on fabricating and handling large satellites.

Specifications: Weight: Approx 640 kg Shape: Cylindrical body Diameter: Approx 210 cm

Launch Date, Launch Vehicle: February 11, 1981 N-II rocket

Comments: Operation terminated December 24, 1984

Satellite Type: Geostationary Meteorol Sat 2 (GMS-2) "Himawari 2"

Major Objectives: This craft performs almost identically as the Geostationary Meteorological Satellite (GMS) launched in July, 1977; is contributing to improving meteorological operations in Japan and to development of weather satellite technology.

Specifications: Weight: Approx 296 kg Shape: Cylindrical body Diameter: Approx 215 cm

Launch Date, Launch Vehicle: August 11, 1981 N-II rocket

Comments: Standing by in orbit

Satellite Type: Communications Satellite 2 (CS-2a) "Sakura 2-a"

Major Objectives: This craft performs almost identically as the Experimental Medium-Capacity Geostationary Communications Satellite (CS) launched in December, 1977; able to handle increased communications demand by using parties and is contributing to development of communications satellite technology.

Specifications: Weight: Approx 350 kg Shape: Cylindrical body Diameter: 220 cm

Launch Date, Launch Vehicle: February 4, 1983 N-II rocket

Comments: Now in operation

Satellite Type: Communications Satellite 2 (CS-2b) "Sakura 2-b"

Major Objectives: Orbiting back-up for CS-2a; same objectives.

Specifications: Same as CS-2a

Launch Date, Launch Vehicle: August 6, 1983 N-II rocket

Comments: Now in operation

Satellite Type: Broadcast Satellite 2 (BS-2a) "Yuri 2-a"

Major Objectives: This craft performs almost identically as the Experimental Medium-Sized Broadcast Satellite (BS) launched in April, 1978; seeks to resolve problems of poor television reception and is contributing to development of broadcast satellite technology.

Specifications: Weight: Approx 350 kg Shape: Box-shape having deployable solar-cell paddle

Launch Date, Launch Vehicle: January 23, 1984 N-II rocket

Comments: Now in operation

Satellite Type: Geostationary Meteorol Sat 3 (GMS-3) "Himawari 3"

Major Objectives: Is improving Japanese meteorological operations and contributing to development of weather satellite technology.
Specifications: Weight: Approx 303 kg Shape: Cylindrical body Diameter: Approx 215 cm
Comments: Now in operation

Satellite Type: Broadcast Satellite 2 (BS-2b) "Yuri 2-b"

Major Objectives: Orbiting back-up for BS-2a; same objectives.
Specifications: Same as BS-2a
Launch Date, Launch Vehicle: February 12, 1986 N-II rocket
Comments: Now conducting test broadcasts

Satellite Type: Marine Observation Satellite 1 (MOS-1)

Major Objectives: To conduct observations of ocean phenomena (primarily color and temperature of sea surfaces) and to perfect basic technology for artificial satellite observation.
Specifications: Weight: Approx 740 kg Shape: Box-shape having deployable solar-cell paddle
Launch Date, Launch Vehicle: Fiscal 1986 N-II rocket
Comments: Under development

H-I PROJECT

Satellite Type: Geodetic Experiment Satellite "Ajisai"

Major Objectives: Used to determine positions of remote islands and to make adjustments in domestic geodetic triangulation net.
Specifications: Weight: Approx 685 kg Shape: Spherical body with diameter of 215 cm, equipped with sunlight reflecting mirror and laser reflecting body
Launch Date, Launch Vehicle: August 13, 1986 H-I rocket (two-stage) test vehicle
Comments: Now in operation

Satellite Type: Experimental Technology Satellite V (ETS-V)

Major Objectives: To demonstrate performance of H-I rocket (three-stage) test vehicle, perfect fundamental technology for geostationary tri-axial satellite bus, accumulate necessary proprietary technology to develop next generation of utility satellites, and conduct mobile communications tests.
Specifications: Weight: Approx 550 kg Shape: Box-shape having deployable solar-cell paddle
Launch Date, Launch Vehicle: Fiscal 1987 H-I rocket (three-stage) test vehicle
Comments: Under development

Satellite Type: Communications Satellite 3 (CS-3a)

Major Objectives: To continue the communications services provided with Communications Satellite 2 (CS-2), cope with growing and

diversifying communications demand, and contribute to development of communications satellite technology.
Specifications: Weight: Approx 550 kg Shape: Cylindrical body Diameter: Approx 220 cm
Launch Date, Launch Vehicle: Fiscal 1987 H-I rocket
Comments: Under development

Satellite Type: Communications Satellite 3 (CS-3b)
Major Objectives: Orbiting back-up for CS-3a; same objectives.
Specifications: Same as CS-3a
Launch Date, Launch Vehicle: Fiscal 1988 H-I rocket
Comments: Under development

Satellite Type: Geostationary Meteorological Satellite 4 (GMS-4)
Major Objectives: This craft performs almost identically as Geostationary Meteorological Satellite 3 (GMS-3) launched in August, 1984; will improve Japanese meteorological operations and contribute to development of weather satellite technology.
Specifications: Weight: Approx 330 kg Shape: Cylindrical body Diameter: Approx 215 cm
Launch Date, Launch Vehicle: Fiscal 1989 H-I rocket
Comments: Under development

Satellite Type: Broadcast Satellite 3 (BS-3a)
Major Objectives: To continue the broadcast services provided with Broadcast Satellite 2 (BS-2), cope with growing and diversifying broadcast demands, and contribute to the development of broadcast satellite technology.
Specifications: Weight: Approx 550 kg Shape: Box-shape with deployable solar-cell paddle
Launch Date, Launch Vehicle: Fiscal 1990 H-I rocket
Launch Date, Launch Vehicle: Under development

Satellite Type: Earth Resource Satellite 1 (ERS-1)
Major Objectives: To perfect active observation technology, to conduct national land surveys primarily for natural resource exploration, and to conduct observations for agriculture, forestries, and fisheries, for environmental protection, for disaster control, and for coastal monitoring.
Specifications: Weight: Approx 1400 kg Shape: Box-shape having deployable solar-cell paddle
Launch Date, Launch Vehicle: Fiscal 1990 H-I rocket
Comments: Under development

Satellite Type: Broadcast Satellite 3 (BS-3b)
Major Objectives: Orbiting back-up for BS-3a; same objectives.
Specifications: Same as BS-3a
Launch Date, Launch Vehicle: Fiscal 1991 H-I rocket
Comments: Under development

1. Communications & Broadcast Satellite Field

Communications Satellites

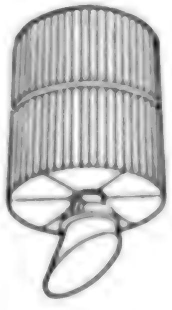
The job of a communication satellite is to receive a radio signal transmitted from point A on earth, change the frequency of this signal and amplify it, then retransmit it to point B on the other side of the earth. Thus the basic function is to relay radio signals between two points that cannot easily communicate via direct radio contact. In order for it to be useful 24 hours a day to both point A and point B, the satellite must appear stationary as viewed from the ground. The two Sakura 2 satellites are in geostationary orbits approximately 36,000 km above the equator at 131 and 136 degrees east longitude, respectively.

Such satellite communications circuits have the following advantages over earth circuits.

- -- Not readily susceptible to topographical blocking
- -- Impervious to disasters
- -- Provide simultaneous service over a broad area
- -- Support economical long-distance communications
- -- Offer flexibility in circuit establishment

The exterior of Sakura 2 is as depicted in Figure 1. The satellite is a cylindrical object with a diameter of 2.2 m and a weight of approximately 350 kg. Solar cells are attached to the entire lateral surface of the cylinder. The instruments that make up the satellite fall into two broad categories according to function. In one category are the so-called mission instruments that accomplish the immediate tasks of the utility satellite. In the other category are the so-called bus functions which supply electrical power, orient the antenna toward Japan, and otherwise make the mission instruments operate normally in space.

Figure 1 Sakura 2



The Sakura 2 has a relaying capacity that is roughly equivalent to 4000 telephone circuits. One of this satellite's features with respect to the bus instruments is its employment of the spin stabilizing method that maintains the satellite in a stable attitude while it is spinning like a top. An alternative method is the tri-axial stabilizing method that maintains the attitude of the satellite (which need not be cylindrical) without imparting a spin to it. (The three axes are the roll axis, yaw axis, and pitch axis.)

Of all the utility satellites, the communications satellite was the first to be used in practical applications, such as the international communications that now span the Pacific and Atlantic oceans. Hence this is a technologically mature field, but, by the same token, also a field in which the question of economy is critical. Simply stated, this is a matter of how inexpensive one can make the cost per telephone circuit. This involves a number of societal factors, but, in general, satellite circuits are usually more advantageous than ground circuits in regions where ground lines are not already well developed.

In Japan, where ground lines are well developed over a small land area, the advantages of satellite circuits are not necessarily being realized, but, as stated earlier, satellite circuits have several advantages over ground circuits, so Japan has created a communications network in which ground lines and satellite circuits complement each other, thereby coping with the overall demands of the advanced information age.

Direct Broadcast Satellites

The direct broadcast satellite, i.e. the so-called broadcast satellite which corresponds to a television tower, is a system that transmits audio and video signals not from an antenna on earth but from an antenna that is 36,000 km above the equator, so that residential viewers can receive the broadcasts directly.

When satellite broadcast systems are compared to earth-based broadcasting, the advantages are identical with those of communications satellites. In addition, however, it is further possible (1) to expand the broadcasting means by using semi-milliwaves, and (2) to diversify broadcast content and utilize the wide-ranging characteristics of satellite communications. Thus satellite broadcasting offers outstanding features.

The Yuri 2 broadcast satellite is depicted in Figure 2. The satellite proper is a box measuring approximately 1.2 m x 1.3 m x 2.9 m and weighing approximately 350 kg. This craft is in geostationary orbit above the equator at 110 degrees east longitude. As to its configuration, the Sakura 2 uses the tri-axial stabilization method and deploys large solar-cell paddles in a north-south orientation.

Figure 2 Yuri 2

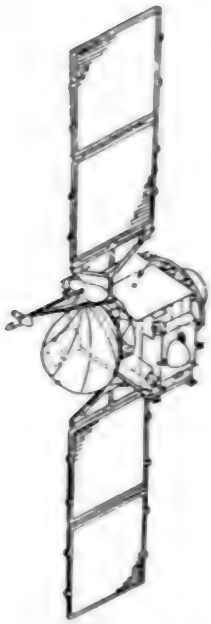
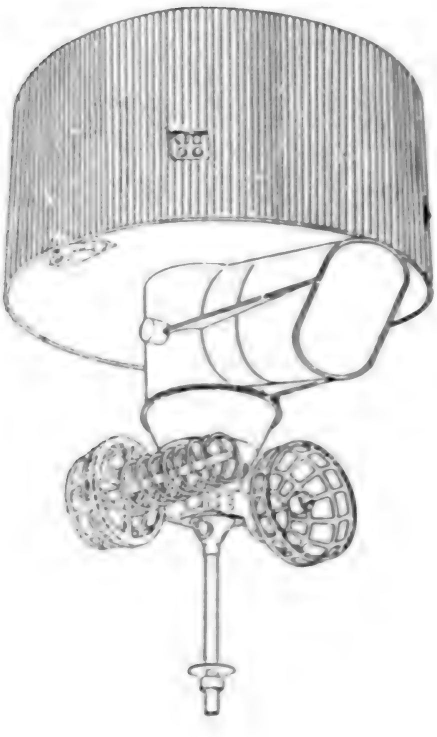


Figure 3 Himawari 3



The functional similarity between broadcast satellites and communications satellites notwithstanding, practical applications of broadcast satellites around the world have been amazingly slow to develop, and there are few examples of such applications. In fact, the Yuri 2--the previously discussed Japanese broadcast satellite that is entertaining the people living on Chichijima--is the first operational utility satellite of its kind in the world. Let us take a closer look at the situation here, where a number of sociological and technical reasons are at play. First of all, whereas communications operations are conducted on a global scale, broadcast operations are activities that are basically conducted within a single country. As already remarked, the wider the area to cover, the more advantagous are satellite systems. Moreover, the development of more advanced reciprocal communications facilities is strongly related to economic development (the two being mutually reinforcing), but this effect is not so apparent with the one-way communications facilities employed in broadcast operations. And, unless the society's communications infrastructure has already been well developed, no great needs develop for anything beyond conventional ground-based broadcasting. The economic level of a society must first be raised to certain levels before its people can enjoy direct satellite broadcasts in their homes. Yet another prerequisite is the extremely

advanced technology necessary to amplify the broadcast signal (having frequencies higher than 10 GHz, as have been authorized for broadcast satellite use) to sufficient strength (several hundred watts) to be readily accessible by home receivers. These are some of the reasons why the global development of direct broadcast satellites has fallen behind. The fact that Japan is now vigorously involved in this field simply means that Japan was the first nation in the world to satisfy all of these conditions.

2. Earth Observation Field

By using the techniques of remote sensing, it has become possible in recent years to continuously observe the earth's surface from artificial satellites, monitoring cloud distribution, ocean conditions, sea ice conditions, and land utilization conditions, as well as detecting the presence of subterranean resources. Such artificial satellites are commonly called earth observation or earth monitoring satellites. Falling into this category are the Japanese meteorological satellite "Himawari," and the Marine Observation Satellite No. 1 that is to be launched in January, 1987.

The meteorological satellite Himawari 3 that has become familiar to many through weather forecasts is perched 36,000 km above the equator at 140 degrees east longitude. From there it photographs cloud movements on the earth with special visible-light and infrared cameras. This equipment takes 25 minutes to photograph clouds appearing in a 20 degree x 20 degree visual range and send the images to earth. From the conditions of these cloud images, it is possible to estimate cloud amounts, wind direction and speed, and the size and movement of typhoons, and to base weather forecasts on these estimates.

The Himawari 3 is depicted in Figure 3. The main unit is cylindrical, as in the communications satellite Sakura 2, and it is similarly a spin-stabilized satellite. The dish-shaped and spiral objects protruding from one end of the main satellite body are antennas for communicating with earth, while the hooded device between the antennas and the main body contain the cameras for photographing the earth's surface.

By the way, how many of you noticed something when you took a look at Figure 3?. Since a spin-stabilized satellite rotates, won't this interfere with the operations of the cameras and antennas? Actually, the main body of the Himawari 3 does indeed spin, but the antennas are always pointed toward Japan, because they rotate, relative to the main body, in the opposite direction as the main body, and with the same rotational speed. An antenna configured in this way is called a "despun" antenna. The antenna carried by the communications satellite Sakura 2 discussed above is also a despun antenna.

The cameras, meanwhile, are fixed to the satellite proper and rotate with it. As one edge of the frame being photographed comes into view the shutter opens, then the camera scans the frame from east to west, and the shutter closes when the other edge of the frame is reached. Scans of north-

south oriented frames are photographed by sequentially shifting the angle of a reflecting mirror inside the cameras. Thus the cameras photograph the earth while turning approximately 1000 times a minute with the satellite. For the visible-light photographs, a photomultiplier tube is employed, providing an image resolution of 1.25 km. The infrared equipment, which can take photographs even at night, employs wavelengths of 10.5 - 12.5 microns, giving a resolution of about 5 km.

Meteorological information is very important and closely related to our everyday lives, so the meteorological satellite developed quickly as a utility satellite. The weather satellite Tyros 3 launched in 1961 by the United States made early discoveries of six hurricanes that developed in the Atlantic that year, and 12 typhoons that developed in the Pacific, quickly demonstrating the importance of weather satellites to the world. Japan launched its first Himawari satellite in 1977, orbiting the Himawari 2 in 1981 and the Himawari 3 in 1984, thereby enabling families sitting in their parlors to view recent cloud images on their TV's.

Ocean, Land Monitoring Satellites

The ability to regularly monitor large areas of the earth's surface should be of inestimable benefit to us in our everyday affairs. Land factors to be observed include topographical changes, plant growth, water utilization, geological conditions, land utilization, and agricultural and forest resources. Sea factors include water temperature, water quality, ocean currents, sea ice, wave conditions, coastal conditions, and marine resources. Environmental polution conditions over land and sea are important.

With regard to observing the earth's surface from an artificial satellite, however, the range visible from a geostationary satellite like the Himawari would be too limited, and one could not observe regions in the high latitudes near the poles. What is needed is rather a satellite that passes over every square mile of the earth at a low altitude. When the earth is observed from a satellite revolving in a so-called polar orbit that crosses the equator and passes over the polar regions, it is possible to view all areas on the earth's surface due to the rotation of the earth. In order to repeatedly monitor the same locations, what is needed is something called regression, with which the satellite will pass directly over the same location after a few weeks as it rides in its orbit. When the orbit is sun-synchronous, passing over the same location at nearly the same precise hour, it is possible to conduct constant-position, constant-time observations. Most earth monitoring satellites fly in a sun-synchronous semi-regressive orbit that comes close to satisfying these conditions.

The observation instruments differ depending on the observation purpose and subject, but the following properties are generally utilized. Substances that occur in nature receive energy from the sun and reflect or emit characteristic electromagnetic radiation (including visible light of course) according to the type and condition of the substance. Thus when the

electromagnetic radiation coming from these substances is monitored and analyzed according to wavelength. the type and condition of the substances can be inferred. This is called observation by passive sensors.

Observation by active sensors, on the other hand, is the method of sending out electromagnetic radiation from the observing device to the observed object, and receiving the radiation that is reflected back.

Japan's Marine Observation Satellite No. 1, scheduled for launch in late 1986, carries passive sensors that use visible light, infrared radiation (which has slightly longer wavelengths), and microwaves (which have yet longer wavelengths). These sensors will be used primarily to monitor sea phenomena--water quality, water temperature, ocean currents, sea ice, and wave conditions, etc.

The Earth Resource Satellite No. 1, another earth monitoring satellite which Japan will launch in fiscal 1990, will have high-resolution active sensors that employ the advanced technology of compound aperture radar to ovserve land areas with the primary purpose of resource exploration.

Future Developments in Utility Satellites

We have so far been discussing the current status of Japanese utility satellites. Once the benefits of utility satellites have been established, more communications and broadcast satellites must be launched in order to continue services, which then give rise to further market demands.

In the field of communications, for example, a demand develops for using utility satellites in mobile communications for aircraft, ships, and automobiles. With broadcast satellites, the demand arises for allocating the limited number of broadcast frequencies so that many regions can receive a variety of broadcasts. Such operations require a satellite to be equipped with a multibeam antenna that can transmit independent signals to a number of desired regions. Another economic demand is that broadcast satellites have longer lifespans.

In order to satisfy these diverse demands, satellites must carry much equipment, have enormous solar cell paddles in order to supply the electric power needed by the equipment, and be loaded with enough control fuel (propellant) to keep the satellite in the proper position and attitude over a long period of time. Thus utility satellites will tend to become larger and larger. The Japanese utility satellites discussed so far have been in the 350-kg class, but these will give way to 500-kg, 1-ton, and then 2-ton devices.

One of the milestones in this trend toward larger sizes will be in the large-scale vehicles called space stations or platforms which fly in a constant orbit. Enormous solar-cell paddles and multibeam antennas will be assembled on these vehicles so that a number of different utility-satellite functions can be combined. The easiest approach, technologically speaking,

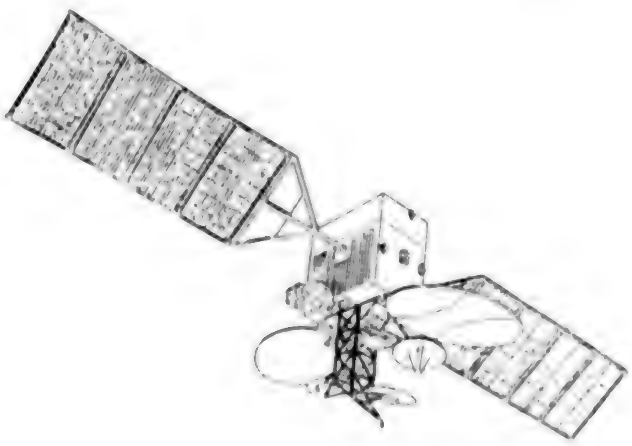
will be to first put a space station in a relatively low orbit, then use this station as a base from which to put platforms into geostationary orbits.

Experimental Technology Satellites

The trend toward larger utility satellites and the diversification of demanded functions will lead to demands for developing new technologies. Before these new technologies and new devices and systems can be used in utility satellites, however, it must be demonstrated that they can withstand the rigors of the space environment. Japan's Experimental Technology Satellite series is designed for this very purpose, i.e. to perform the role of forerunner to the utility satellites. Models I through IV have already been orbited and have made contributions to the development of Japan's utility satellites.

The model V weighed 550 kg when it was launched into geostationary orbit. It carries a diversity of instruments for perfecting Japan's domestic space technology, including the mobile communications technology mentioned above. The model VI is designed to perfect the tri-axial stabilization type bus device technology which will be used in the 2-ton class satellites. It will carry a multibeam antenna and experimental inter-satellite communications equipment. The model VI will have a height of approximately 8 meters, making it much larger than previous Japanese satellites. (Cf. Figure 4.)

Figure 4 Experimental Technology Satellite Model VI



Data Relay Satellites

Space vehicles such as earth monitoring satellites which fly in orbits lower than geostationary orbits cannot always be seen from Japan, and during the times when not within the line of sight, these vehicles cannot be communicated with directly from Japan. One possible solution to this problem is the use of what is called a data relay satellite to relay communications between Japan and satellites which are out of the line-of-sight range.

If such data relay satellites are combined with earth monitoring satellites, then Japan will be able to receive data from satellites anywhere in the world. Studies are now being done on implementing such satellites in Japan.

Epilogue

The expansiveness of space is unlimited. But when we consider utility satellites, we realize that, even though space is unlimited, usable space is limited and precious. The geostationary satellite orbit--in which satellites behave as though they were standing still as seen from earth--is a one-lane highway which circles the earth along the equator at an altitude of 36,000 km.

If the nations of the world vie with one another in launching geostationary satellites in the future, the geostationary satellite orbit may become fully populated with spacecraft. One solution to this problem is to use orbital platforms which combine multiple satellite functions. An operational solution is to have as many nations as possible use each satellite.

In terms of both technology and operations, we will have to emphasize international cooperation so that this limited resource can be used effectively for all mankind.

Materials Experiments in Space (FMPT)

Tokyo PUROMETEUSE in Japanese Jan 87 pp 63 - 65

[Article by Space Experiments Group, National Space Development Agency]

[Text] 1. Significance of Materials Experiments in Space Environment

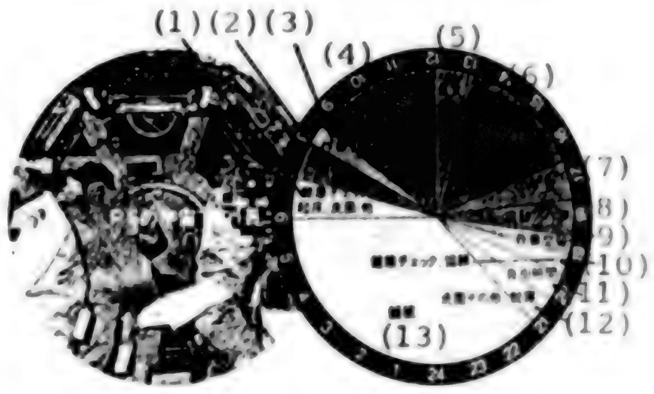
The utilization of space, as typified in the utility satellites, has so far taken advantage of the altitude and position of artificial satellites to act as human eyes and ears. Space, however, has many environmental peculiarities not found on earth, including extremely low gravity, expansive high vacuum, unlimited heat-sink characteristics, and an abundance of solar energy. The low-gravity property alone can be used to perform experiments in an environment that is not influenced by gravity, convection, or static pressure. Such experiments have been conducted already in the very limited

confines of the Apollo, Soyuz, and Skylab vehicles. These activities suggested that such experiments were useful, but it was with the advent of the space shuttle that they came to be more commonly conducted.

In today's advanced fields of science and technology, experiments conducted under extreme conditions have come to occupy an important position, and space experiments which utilize the peculiarities of the space environment are ideal in some cases. Thus Europe and America attach high importance to space experiments as sources of new knowledge which can even give birth to new industrial fields.

Nevertheless, for the human race, which has thus far lived on the earth, there still remains an overwhelming number of problems and unknowns which must be resolved before the space environment can be fully utilized. The costs of implementing such utilization, moreover, are enormous. Accordingly, we must begin with the tasks of correctly understand the space environment and studying effective ways to employ it. The First Materials Experiment Project (FMPT) is being planned as the first step in such wide utilization of the peculiarities of space. In this project, human beings will be deployed in space to conduct space-materials and life-science experiments which can be analogized relatively easily on earth and readily lead to practical applications. This project will employ in space human functions that are beyond the capabilities of machines, such as comprehending diverse information in a short time, making comprehensive judgments, coping with new situations, and conducting suitable processing operations.

Figure A Day in Space for a Payload Specialist (PS)



Key:
1. Wake up, wash up, health check, etc.
2. Breakfast
3. Work succession [from earlier shift]
4. Experimentation, other work
5. Lunch

6. Experimentation, other work
7. Dinner
8. Experimentation, other work
9. Work transfer [to next shift]
10. Health check, conference
11. Free time
12. Bath, etc., preparation for bed
13. Sleep
14. One day in space for a PS

2. Japanese First Materials Experiments

The National Space Development Agency (NASDA) is moving ahead with its First Materials Experiment Project (FMPT) in which it was to use the space shuttle and space lab in late 1987 (now being rescheduled due to the Challenger accident). This project involves a Japanese payload specialist who will fly as an astronaut and conduct experiments on the space shuttle/space lab.

The objectives of FMPT are as follows.

-- Demonstrate the usefulness of space experiments and contribute to further developments in the field.
-- Perform as many experiments as possible, since this is the first battery of serious space experiments.
-- Develop experimentation systems to efficiently perform many experiments using limited equipment resources.
-- Seek to conduct the FMPT experiments smoothly and appropriately, and succeed in sending a Japanese PS into orbit in order to conduct Japan's first manned space flight.
-- Develop experimental systems, and conduct the selection, training, and health monitoring of the PS with indigenous Japanese technology, and endeavor to accumulate know-how in this field.

As part of FMPT, 22 materials experiments and 12 life-science experiments, for a total of 34 experiments, have been selected by the Space Activities Commission for implementation. These, together with three NASA space experiments, are to be conducted on the shuttle/lab as the Space Lab J Mission. The entire flight may be summarized as follows.

-- Lift-off <from Kennedy Space Center>
-- Orbit <circular orbit, approx 300 km altitude, 57-degree orbital inclination>
-- Duration of flight: Approx 7 days
-- Shuttle orbiter attitude: gravity inclined
-- Crew: 7 astronauts

The equipment to be used in these experiments has now been designed and is in the fabrication and testing stages.

Most of the experimentation equipment is mounted on shelves called racks, and is to be mounted and launched sequentially aboard the space lab/shuttle. This development work is very special, involving experiments that will be done by humans in the sealed environment of the space shuttle/lab, work that has not been attempted before by NASDA. The project must be carried on between the NASDA researchers and NASA on a trial-and-error basis. This field of development differs from previous rocket and satellite development.

Three PS candidates for the Space Lab J flight were selected two years ago and retained as NASDA employees. They are now in training.

Figure Space Lab Where Materials Experiments Will Be Conducted

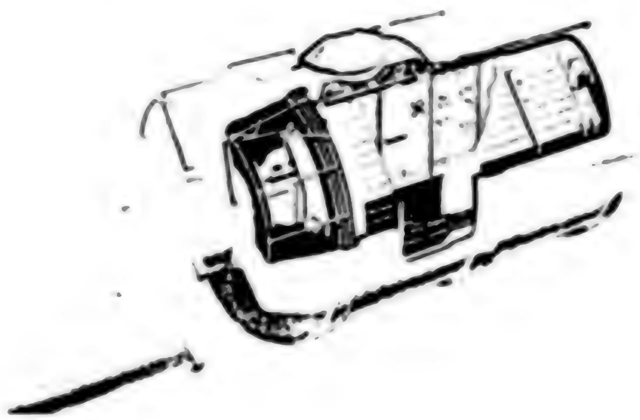


Figure Shuttle From Lift-Off to Landing

Space Station

Tokvo PUROMETEUSE in Japanese Jan 87 pp 67 - 71

[Article by Space Experiments Group, National Space Development Agency: "First Step Toward Life in Space"]

[Text] 1. Living in Space

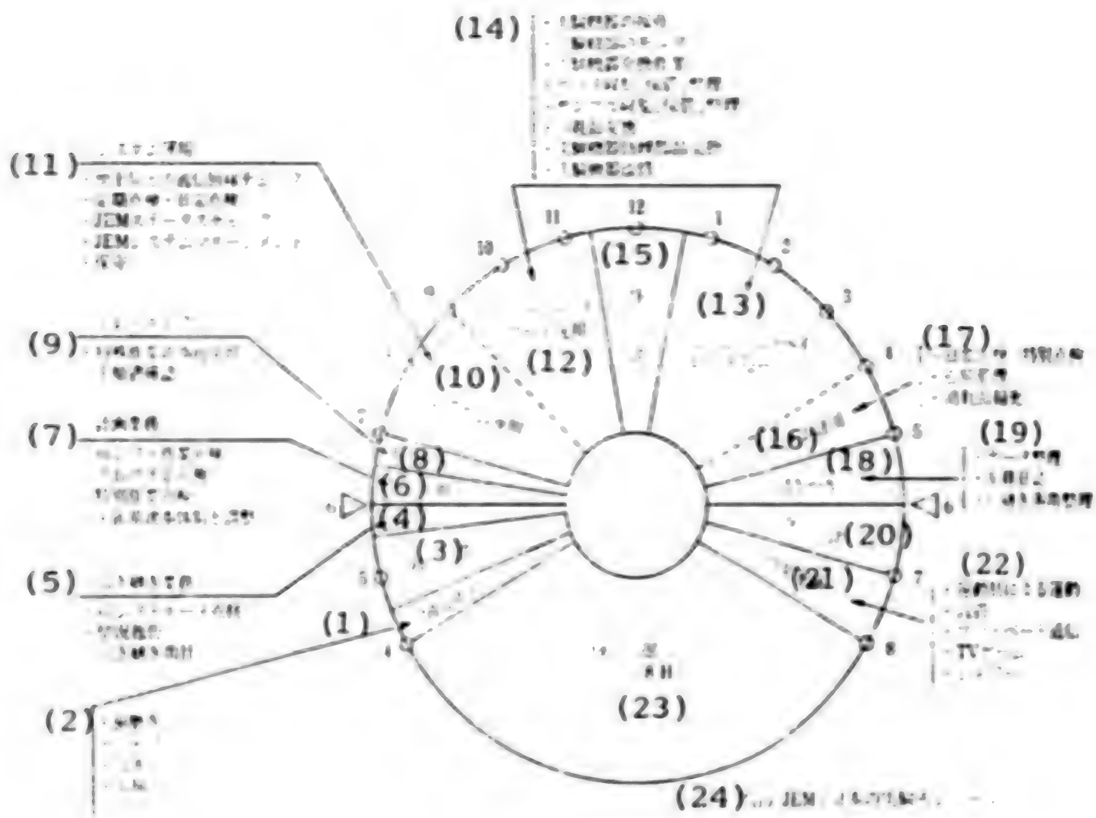
The environment in space--with its vacuum, extreme temperature differences, solar winds, and near weightlessness--is very different from the environment on the ground. Living in space requires the use of complex life support systems, and all food must currently be supplied from the earth. Space life also involves various limitations and risks. Nevertheless, almost everyone who has ever flown in space speaks of its magniticance. Maybe humans are naturally adapted to living in space. Once the space station is achieved and becomes a permanent base of operations, life in space will begin in earnest.

Let us take an introductory look at life aboard the space station. The most striking peculiarity is that of weightlessness, which causes everyone to adopt a slightly hunched-over posture in which the knees are slightly bent. Naturally, special techniques are required when eating or moving. Some people may become space-sick, but they will probably quickly recover. In other respects, life in space is as comfortable as it is on earth. A crew of 6 - 8 persons is now contemplated, two of which will handle the operations of the station itself, with the remaining 4 - 6 people operating the experimentation equipment and performing evaluations and analyses, etc. The crew will be divided between two 12-hour shifts. An example schedule is given in Figure 1. Some activities will be conducted outside the vehicle in spacesuits, usually by a team of two astronauts. Operations outside the spacecraft are limited to 6 hours. Hence the astronauts will have a busy workday.

Key to Figure 1 (cf. next page):

1. Personal hygiene
2. Brush teeth / shower / laundry / house cleaning
3. Breakfast
4. Work transition [from previous shift]
5. Inspect data from previous shift / report on conditions / transition routines
6. Planning
7. Inspect work of previous shift / check schedule for day / check special operations / coordinate with space station operations
8. Training
9. Preliminary training for special operations / check procedural manuals
10. System operations
11. Check communications channels with ground stations / conduct regular and periodic checks / check JEM status / JEM systems management / maintenance

Figure 1 One-Day Crew Schedule (Example)



Key to Figure 1 (continued):
12. Mission payload operations
13. Mission payload operations
14. Operate experiment equipment / monitor experiment instruments / replace experiment equipment / collect, store, and collate data / collect, store, and collate samples / replace expendable supplies / repair experiment equipment & change part / improve experiment equipment
15. Lunch
16. System operations
17. Regular & special checks / monitor inventories / replenish expendable supplies
18. Work transition
19. Collate data / update daily journal / complete transition routines
20. Dinner
21. Recreation, exercise

22. Exercise with exercising equipment / read books / personal communications, letter writing / television, games / shower
23. Sleep (8 hours)
24. Note: JEM = Japanese Experimental Module

Specialized training is required before one may become a space station crewmember, but the day is probably coming when ordinary people can take trips into space. Subsequent developments in space living could take place very rapidly, with people soon living on the moon or on Mars.

2. International Space Station

(International Cooperation)

In January, 1984, President Reagan stated in his State of the Union message that within 10 years a permanent space station would be developed under international cooperation.

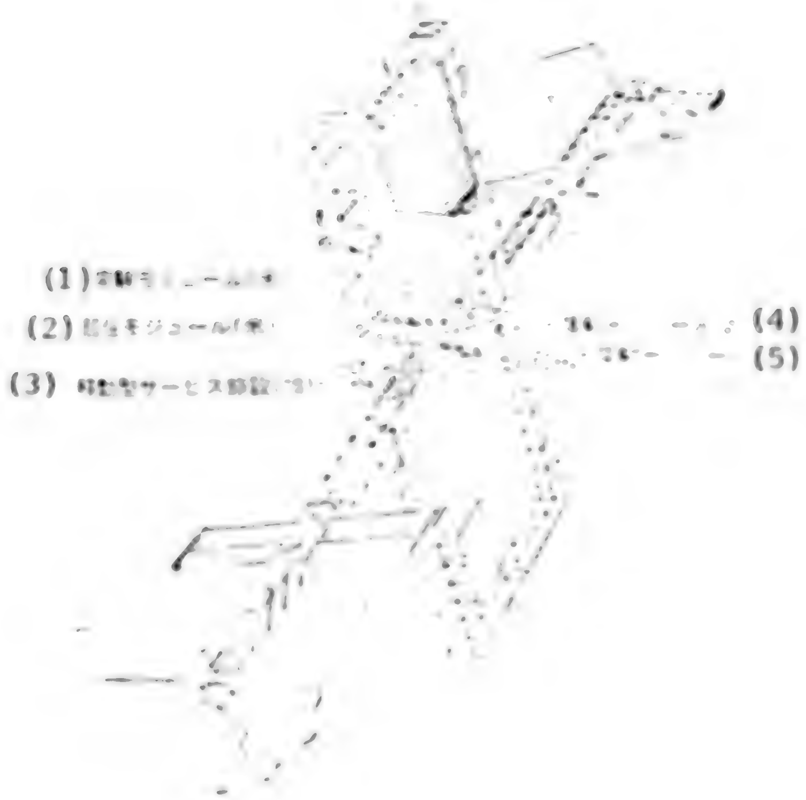
In June of the same year, the space station project was discussed at the London summit, and a decision was made to go ahead with the project under the cooperation of the participating nations.

From April to June, 1985, Japan, Canada, and the ESA (European Space Authority) exchanged memoranda with the United States pertaining to cooperation in the preliminary design stage of the space station project, and each country began working on concrete plans for participating in the project, with full-scale development to begin on the space station in 1987.

As presently conceived, the space station will be made up of four modules, three of which will be laboratories, with the United States, ESA, and Japan each responsible for building one of them. The fourth module will be the crew-quarters module, developed by the United States.

Transportation and communications to and from the space station will be handled mainly by the space shuttle and data relay satellites (TDRS) developed by the United States, but it is possible that transportation and communications vehicles developed by other nations will be used as well. There is a good possibility that Japan's H-II rocket may be used to transport water, air, and food supplies (procured in Japan) to the station for use by its crew. It is also a real possibility that Japan's data relay satellite (DRTS) will be used to transmit large volumes of data directly to Japan or other nations. The space station will involve continual manned activity, and no breakdown of such access means as the transport or communications systems can be permitted. The efforts of Japan and the ESA will be critical in this regard. In any event, the success or failure of the permanent manned space station will certainly depend on how well the policies of international cooperation and can be developed and maintained.

Figure Space Station Configuration



Key:
1. Experimental module (United States)
2. Crew quarters (United States)
3. Mobile service facility (Canada)
4. Experimental module (Europe)
5. Experimental module (Japan)

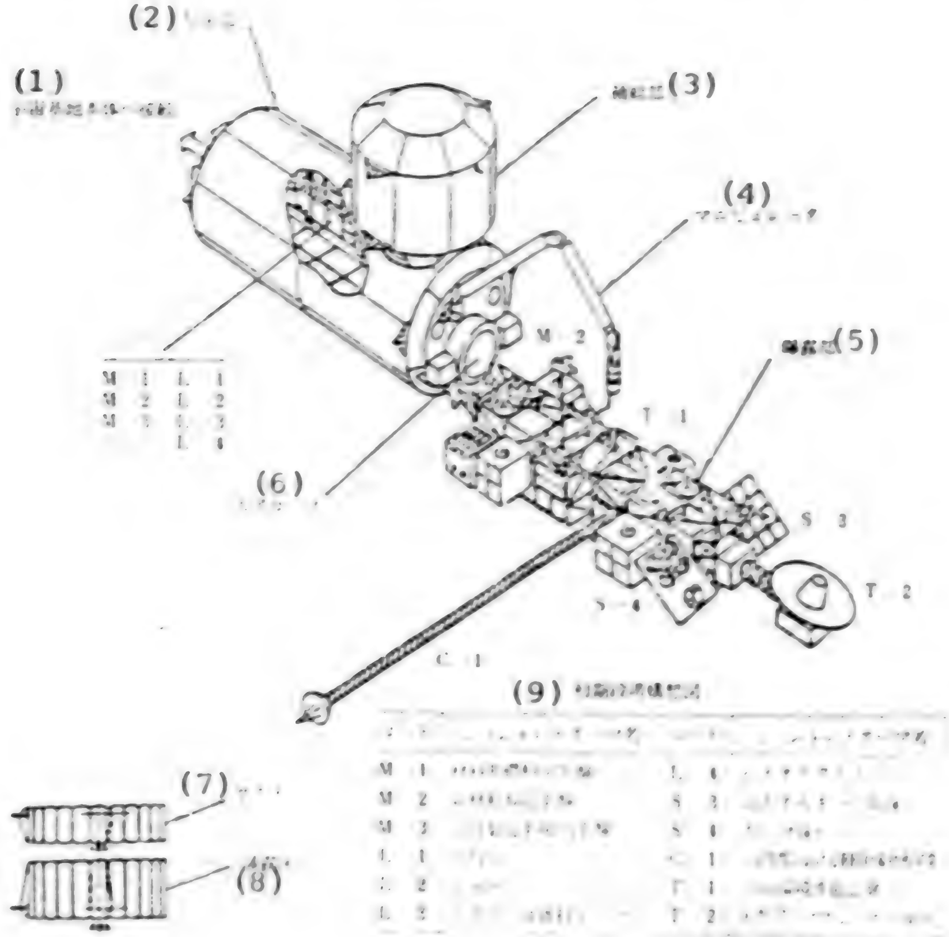
3. Overview of Japan's Space-Station Plans

The space station will be a facility for joint international use for the purposes of adding to our intellectual capital and developing creative science and technology, as these pertain to our commonly held resources in space, and it will constitute a basic framework for future operations in space. The concept is a bold attempt to develop new science and technology through a large-scale international project. The basic guidelines for Japan's participation in the space station project are being hammered out in the Special Space Station Committee of the Space Activities Commission. The following basic guidelines were contained in the interim report which the special committee issued in July, 1986. Japanese participation in the

space station project is very significant for a number of reasons. It will promote broader space activities in scientific and applications fields and the practical utilization of the space environment, as well as promote science and technology in general through development of advanced technologies. It will also enable Japan to make contributions to the international community. The space station is to be operational for a period of 20 to 30 years. Japan's participation in the initial stages of this project with the development and operation of the multipurpose experimental module (Japanese Experimental Module = JEM)--which will be attached to the space station proper and support a broad range of scientific and technological experiments and development--is ideal. As depicted in Figure 2, the JEM is made up of a pressurized unit, an exposed unit, and a supply unit. The pressurized unit will support experimentation at low gravity involving manned operations. These experiments will be in various fields, such as materials and life science. The exposed unit is a facility that is exposed to space for the purpose of conducting engineering experiments, communications experiments, scientific and earth-monitoring observations, and some of the materials experiments. The exposed unit will be accessible from the pressurized unit via a mechanical manipulator and an air lock to permit the exchange of equipment and samples and the assembly of space structures, etc. The supply unit will be used in the replenishment, storage, and transport of materials, gas, and equipment, as needed for the experiments, and will also serve as an emergency escape facility should the JEM crew become trapped inside the module. The basic policies with respect to Japan's participation in the space station project--focused primarily on the development and operation of the JEM--are as follows. (1) Participation will be under the direction of the government, as with the other participating nations. (2) Japan's needs in a wide number of fields will be appropriately reflected in the space station. (3) Efforts will be made to enhance Japan's indigenous developmental capabilities, while promoting harmony between national interests and other space development projects, in order to make rapid advances in technological capabilities so as to facilitate broad space activities by Japan in the future. (4) The mutual utilization of the various constituent elements of the space station, as agreed by the participating nations, will be promoted from the perspective of coping flexibly with Japan's wide-ranging needs and effectively using the space station in a context of limited resources. Within the framework of these guidelines, preliminary design work will continue until the end of 1986, and consultations with the United States and the other participating nations will be actively encouraged in the interest of promoting cooperation during the developmental stages and thereafter.

Key to Figure 2 (cf. next page):
1. Connects to space station proper
2. Pressurized unit
3. Supply unit
4. Manipulator
5. Exposed unit
6. Air lock
7. Gas section

Figure 2 Japanese Experimental Module--Baseline Configuration



Key to Figure 2 (continued):

8. Exposed section
9. Legend for Configuration in Initial Stage
   - M-1 Materials--basic scientific experiments
   - M-2 New materials fabrication experiments
   - M-3 Space fabrication implementation experiments
   - L-1 Biology
   - L-2 Space medicine
   - L-3 Ecological life support systems
   - L-4 Biotechnology
   - S-3 High-energy cosmic rays
   - S-4 Gamma ray bursts
   - C-1 In-space RFI countermeasure technology development
   - T-1 Space environment performance tests
   - T-2 Large antenna system technology

Earth Observation Satellite MOS-1

Tokyo PUROMETEUSE in Japanese Jan 87 pp 4-7

[Article: "Watching Earth From Space"]

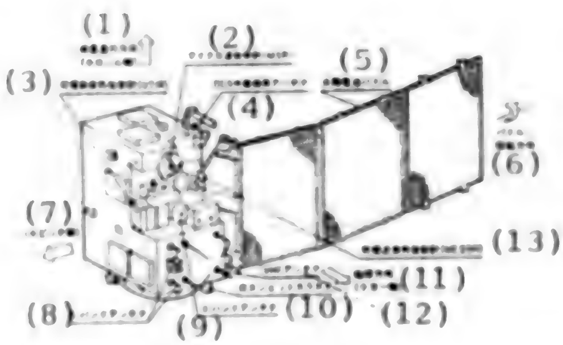
[Text] Industrial development and cultural advances are now presenting mankind with new problems such as how to optimally utilize the available land and resources, and redevelop the earth, while preserving the majestic beauty of the planet. In order to do these things, we must first look at the earth very carefully and dispassionately.

Part of an earth observation satellite project being promoted on a global level, the Marine Observation Satellite No. 1 (MOS-1) is the first earth observation satellite developed in Japan. This satellite project is being conducted by the Science & Technology Agency. The satellite is scheduled for launch in late May, 1987.

High-Tech Implemented MOS-1

The MOS-1 is made up of the satellite proper and the observation instruments. The observation instruments carried include such high-tech units as a visible near-infrared radiometer (MESSR), visible thermal- infrared radiometer (VTIR), and microwave radiometer (MSR).

Figure



Key:
1. Direction of satellite travel (+ roll axis)
2. Microwave radiometer (MSR)
3. Visible thermal infrared radiometer (VTIR)
4. Antenna for DCS relay unit
5. Solar cell paddle
6. Direction of paddle revolution
7. (+ pitch axis)
8. S-band antenna

9. X-band antenna
10. Gas jet thruster
11. Direction of earth (+ yaw axis)
12. VHF antenna
13. Visible near-infrared radiometer (MESSR)

Operating Organization for Optimizing MOS-1

The operating organization for the MOS-1 embraces a number of areas, including tracking and controlling the satellite, devising and regulating the plans for monitoring with the obvservation instruments, mission operations management (checking the observational data), accessing and processing the observational data, and distributing the processed data to the end users. A complete operating organization has been prepared that includes tracking and control stations and earth observation centers.

Table Satellite Specifications

Orbit

Sun-synchronous semi-regressive orbit
Orbit altitude: Approx 909 km
Angle of orbit inclination: Approx 99 degrees
Regression period: 17 days (westward shift)

Attitude Control

Tri-axial attitude stabilization system
(controlled bias momentum system)
Attitude control precision:
Attitude angle (3 sigma)
Roll, pitch: +/-0.4 degrees or less
Yaw: +/-0.9 degrees or less
Attitude stability (3 sigma)
Roll, pitch: +/-0.016 degrees/second or less
Yaw: +/-0.05 degrees/second or less

Shape, Dimensions

Box-shaped, equipped with single wing-type solar-cell paddle
Main unit: 1.26 (width) x 1.48 (depth) x 2.4 (height) m
Solar-cell paddle: 2.0 (width) x 5.28 (length) m (when deployed)

Weight

At launch: 740 kg

Power Generated

BOL: 640 W or more
EOL: 540 W or more

Lifespan

Design lifespan: 2 years

Reliability

Probability of survival: Cummulatively 0.5 or greater

Launch

January - February, 1987

Launched by N-II rocket from Tanegashima Space Center

The MOS-1 carries three types of sensor, namely the MESSR, VTIR, and MSR. Each of these is a passive sensor that captures reflected solar radiation or radio waves emitted from earth.

The MESSR observes the color of sea surfaces and ground information over land areas by means of the visible-infrared wavebands. The VTIR uses the visible/thermal-infrared bands to observe sea surfaces and high-level water vapor, as well as the ground thermal distribution, over wide areas. The MSR captures two microwave radiation frequencies from the earth's surface, thereby monitoring water vapor amounts, snow, and water. The respective approximate observational widths are 100 km for one MESSR system, 185 km for two MESSR systems, 1,500 km for the VTIR, and 320 km for the MSR, with the acquired information transmitted to earth in real time.

Visible Near-Infrared Radiometer (MESSR)

This is an electronic scanning radiometer that captures solar radiation reflected from the earth on two visible wavebands and two near-infrared wavebands. The craft is equipped with two camera systems that are oriented parallel to the direction of satellite travel. Using 2,048 detector elements, the achievable resolution is equivalent to 50 miles on the earth's surface. (Cf. Figure 1)

Visible-Thermal Infrared Radiometer (VTIR)

Observation is performed in three thermal-infrared wavebands in order to capture thermal radiation from the earth's surface in two visible wavebands. The scan width is a wide 1,500 km, and the continuous monitoring of specified regions is supported. (Cf. Figure 2)

Microwave Radiometer (MSR)

The craft carries a radio wave sensor that continuously scans the earth's surface along the path of the satellite, with a cone having a width of approximately 320 km, by rotating a parabolic antenna carried on the satellite. Information is gathered, both day and night, on water vapor quantities above the oceans, water amounts, sea ice, and accumulated snow. The resolution is 32 km on the 23.8 GHz band and 23 km on the 31.4 GHz band. (Cf. Figure 3)

Figure 1 MESSR Configuration

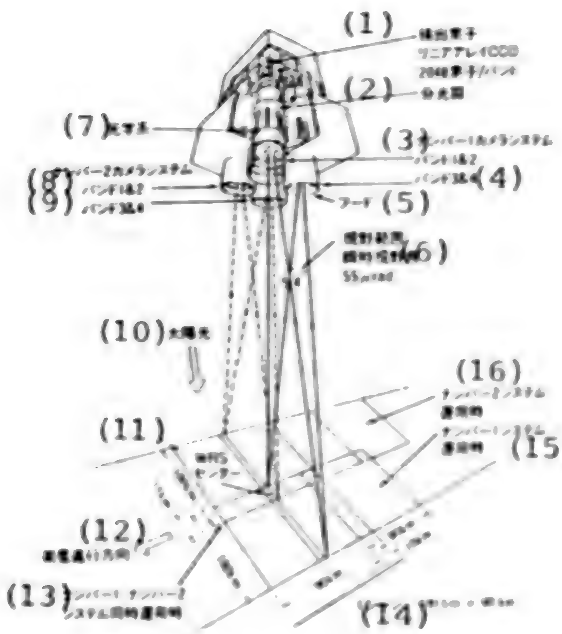
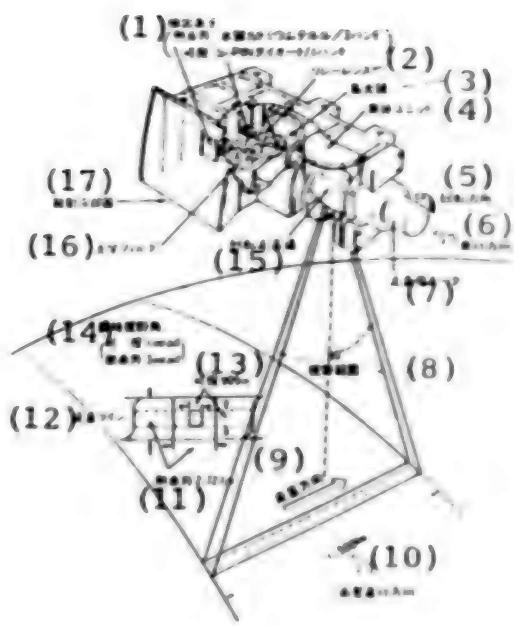


Figure 2 VTIR Configuration

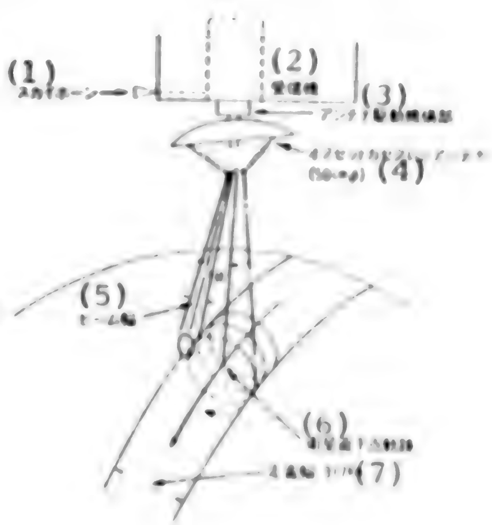


Key to Figure 1:
1. Detector elements, linear array CCD, 2048 elements/band
2. Spectroscope
3. Number 1 camera system, bands 1 & 2
4. Bands 3 & 4
5. Hood
6. Visual range: Instantaenous visibility angle 55 microradians
7. Optical system
8. Number 2 camera system, bands 1 & 2
9. Bands 3 & 4
10. Sunlight
11. WRS center
12. Direction of satellite travel
13. When number 1 and number 2 systems are operating simultaneously
14. One scene: 100 km x 90 km
15. When number 1 system is operating
16. When number 2 system is operating

Key to Figure 2:
1. Detector elements
 (Thermal infrared: mercury cadmium tellurium / 3 bands
 Visible: Si-PIN diode / 1 band)
2. Relay lens
3. Converging mirror

4. Black body unit
5. Direction of revolution
6. Direction of flight
7. Scanning motor
8. Visual range
9. Scanning direction
10. Direction of satellite travel
11. Thermal infrared 2,727 m
12. Scan line
13. Visible 909 m
14. Instantaenous visibility angle
    (Visible: 1 mrad
    Thermal infrared: 3 mrad)
15. Revolving scanning mirror
16. Optical filter
17. Cooling radiator

Figure 3 MSR Configuration



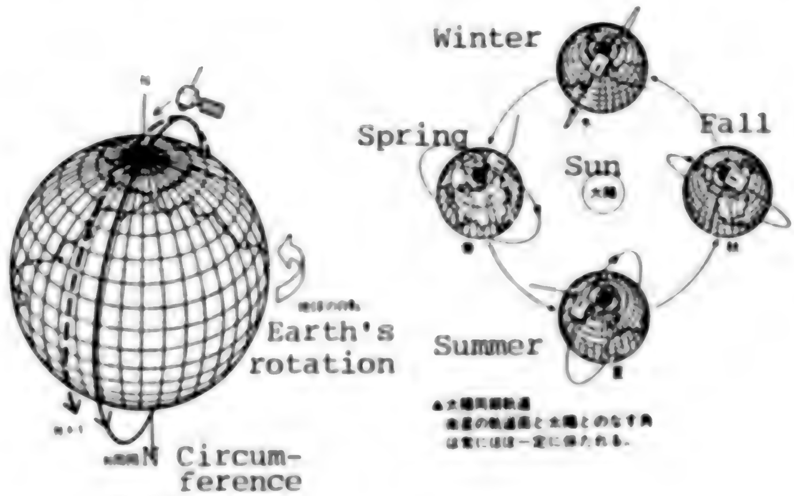
Key to Figure 3:
1. Skyhorn
2. Receiver
3. Antenna drive mechanism
4. Offset Cassegrainian antenna (50 cm phi)
5. Beam width
6. Path directly beneath satellite
7. Scan width 317 km

Repeat Observations at Same Time Zone of Every Area on Earth

MOS-1 Orbit, Track

The MOS-1 travels in a sun-synchronous semi-regressive orbit at an altitude of approximately 909 km and an orbital inclination of approximately 99 degrees. It crosses the equator from north to south, orbiting the earth with a period of approximately 103 minutes, or roughly 14 times a day. The path of each orbit is different due to the earth's rotation, so that the craft makes 237 orbits in 17 days, returning to its original track on day 18 (orbit 238). In other words, it passes over almost every area of the earth's surface every 17 days, making it possible to repeatedly capture data from the same region. Hence the MOS-1 travels in a sun-synchronous semi-regressive orbit in which the angle subtended by the orbital plane and a line connecting the earth and the sun is maintained constant.

Figure The angle formed by the sun and the plane of the satellite's orbit is kept nearly constant.



Final Check To Insure Launch Success

An earth observation system employing artificial satellites periodically monitors a wide range of the earth's surface, constituting an important surveying means for the effective utilization of land and resources and for the preservation of the environment.

The MOS-1, a product of the most advanced space technology, is now waiting to be launched in order to monitor the seas, the mountains, and the continents of a new earth.

Photo 1 Following final inspection and servicing, the rocket is transported on a special trailer to the servicing tower at the launch point. (Shown is the first stage, overall length = 22.4 m, diameter = 2.4 m.)

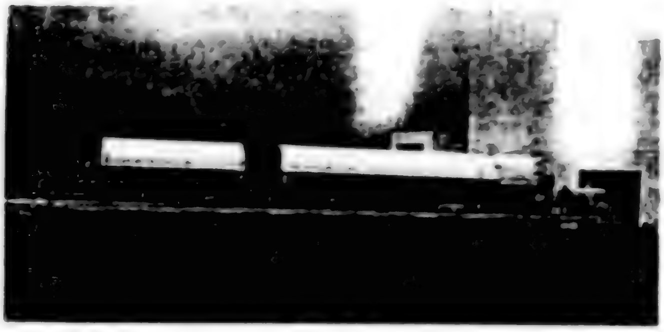


Photo 2 Interior of satellite fairing, a cover to protect the satellite from air forces and heat.

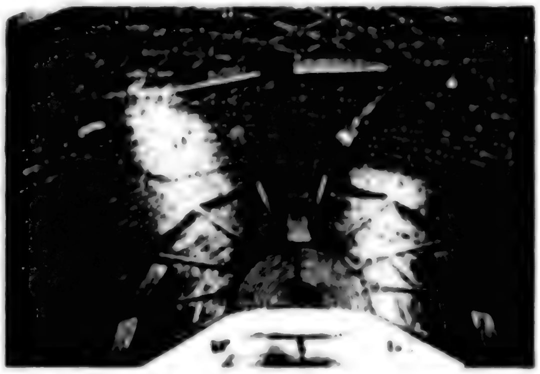
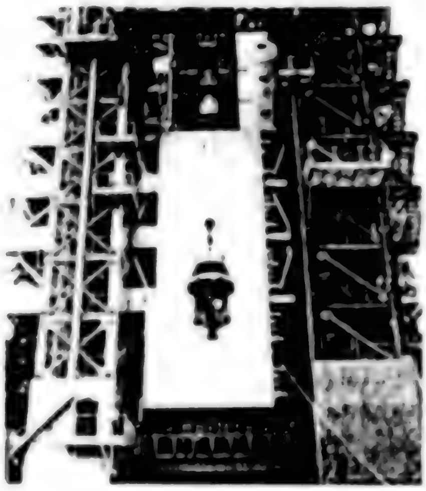


Photo 3 Second stage assembly on service tower. First stage already stands inside service tower.



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MITSUBISHI MU-300 AIMS AT FC-X

Tokyo AEROSPACE JAPAN in Japanese Dec 86 pp 37-41

[Excerpt] Advantages of Domestically-Produced Aircraft Emphasized

Mission Aptitude of MU-300

There is a question as to whether the MU-300, originally designed as a business jet, can satisfy all the requirements of a flight inspection aircraft under consideration for the Air Self-Defense Force. First, the cruising capacity of the MU-300 is a concern.

The flight inspection aircraft of the Air Self-Defense Force must cover all Japan from Hokkaido to Okinawa because its mission is also to inspect the air bases of the Maritime Self-Defense Force and the navigation assistance facilities of the Ground Self-Defense Force in addition to the Air Self-Defense Force bases. The existence of Marcus Island becomes a special problem as it is located far away in the southeastern ocean (located 1,055 nautical miles, 1,945 km southwest of Iruma Base, the base of the flight inspection unit).

Since an ordinary MU-300-10 has a cruising range of 1,320 nautical miles (instrument flight, NBAA rule, and contingency fuel for 200 nautical miles included), an MU-300 from Iruma can fly to Marcus Island. However, it will be impossible to calculate if it can fly back to Iruma Base in case of an unexpected sudden change of weather.

An article pointing this out was carried in this magazine (No 71, September 1986). It received a strong counterargument and protest from Mr Baba of Mitsubishi Heavy Industries, Ltd. The opinion of Mitsubishi Heavy Industries, Ltd. will be introduced here. Hitoshi Baba of the Aircraft Division of Mitsubishi Aircraft and Tank Industries Headquarters says: "A 200-gallon fuel tank will be installed in the rear part of the fuselage of the MU-300, which is under consideration as the flight inspection aircraft of the Air Self-Defense Force. Thus, its cruising range will be extended to 1,865 nautical miles (six crew and passengers, 5 percent initial fuel, contingency fuel for 30 minutes included). With this cruising range, even if it is impossible to make a round trip to Marcus Island, it is possible to divert

to Iwo Jima, 692 nautical miles from Marcus Island, if it cannot land at Marcus Island flying from Iruma. Further, since it is possible to make a round trip to Iwo Jima from Iruma and a round trip to Marcus Island from Iwo Jima, there will be no problem in actual operations."

Further, operation at Iruma or at Iwo Jima is quite possible because the maximum takeoff weight of the MU-300 flight inspection aircraft is 17,200 pounds and the takeoff distance is 1,410 meters in this case.

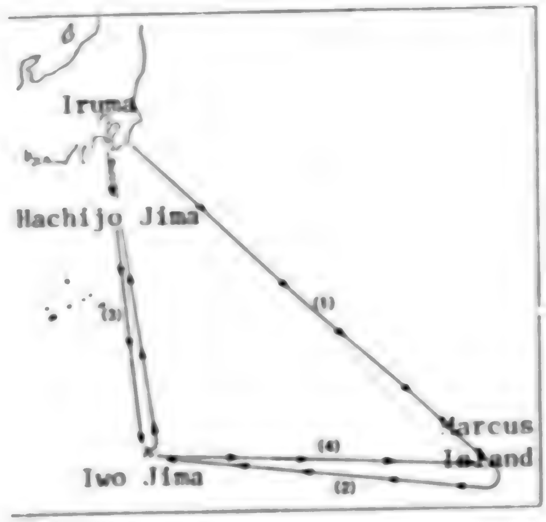
(1) Possible to fly from Iruma to Marcus Island.

(2) Possible to divert to Iwo Jima when impossible to land on Marcus Island. (Diversion during flight)

(3) Possible to make a round trip from Iruma to Iwo Jima. (Low-level approach is possible at Iwo Jima)

(4) Possible to make a round trip from Iwo Jima to Marcus Island. (Low-level approach is possible at Marcus Island)

(Calculation condition: Windless, standard atmospheric condition)



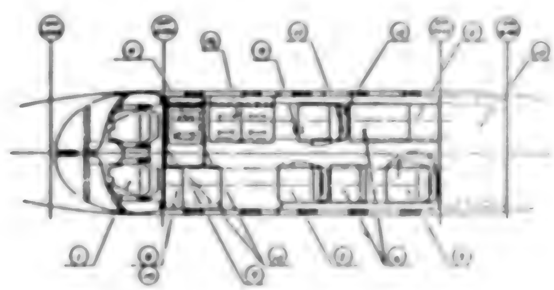
[Figure:] Cruising Capacity to Marcus Island

Cabin space will be addressed next. The MU-300-10 is included in the small aircraft class according to its price in the United States. On the other hand, many large higher-class aircraft such as the Canadair Challenger 601, Dassault Breguet Falcon 900, and Gulf Stream IV are rumored to be candidates for the flight inspection aircraft, and the Citation and Learjet 36A are considered to be candidates in the MU-300 class. However, there are many types of business jets and there is a great difference in cabin space between the former large aircraft and the latter small aircraft. There is a question as to whether the MU-300, belonging to the small aircraft class, can be operated satisfactorily loaded with flight inspection equipment.

Baba explains on this point: "After examining the flight inspection systems manufactured by Litton, (Shell), (Gull), and Furuno, we found that any of these systems can be installed on the aircraft. For example, six seats (seats for inspectors are included) can be secured in addition to the two seats for the crew even if the Furuno Electric Company system is installed which requires the largest space of these systems. Further, if the Litton system is used, seats for five-seven people can be secured in addition to the seats for two crew members. Therefore, it can be utilized as a transport for VIP's as well as a flight inspection aircraft. At any rate, there will be no problem because sufficient cabin space required for a flight inspection aircraft can be secured."

Katsuhiko Ito of the Business Department of Mitsubishi's Nagoya Aircraft Plant adds concerning cabin space: "It is certain that the cabin of the MU-300 is a little narrower than that of large higher-class aircraft such as the Gulf Stream. But, I think the cabin of the MU-300 is the widest compared with that of a small-class aircraft such as Learjet and Citation. The flat floor of this aircraft is also a big characteristic. A flat floor heightens the degree of freedom of arrangement in the aircraft in addition to easy installation of flight inspection equipment. In some other aircraft the floor of the passage part is lowered and the ceiling is raised, but this sometimes causes people to stumble or trip at this different level after a long flight. This seems to be a good idea, but actually it is not very popular. The MU-300 is designed giving much consideration on its habitability. For instance, the fuselage section is designed to make the portion of the passenger seats widest and elliptic to provide overhead space, and the beams of the main wings are designed concave in order not to protrude into the cabin. Therefore, it is believed that the crew and passengers do not become very tired even if they conduct long flight inspection work, etc. in the MU-300."

Inside Arrangement of Flight Inspection Aircraft (Eight Seats)



Arrangement in Flight Inspection Mission
(Eight Seats for Crew and Passengers)

No	Name	No	Name
1	Pilot's se t	9	TV camera
2	Crew seat (one person)	10	Fuel Tank
3	Inspector's revolving seat	11	Fire extinguisher
4	Seat sideways (also toilet)	12	First aid kit
5	Rack	13	Curtain
6	Consoles A & B	14	Paper box
7	Storage	15	Seats sideways (two persons)
8	Galley		

Advantages of the Introduction of MU-300

In addition to these characteristics of the MU-300, Mitsubishi is asked to evaluate the economy of the MU-300. The three large aircraft (Gulf Stream IV, CL-601-Challenger, and Falcon 900) probably have no problem in cruising range and cabin space, but the purchasing price of the aircraft is another problem. If the prices (basic body price) of these large aircraft and that of the MU-300 are compared, the price of each large aircraft is expensive, about 3.5 to 5 times that of the MU-300 (5-6 times according to the investigation of Mitsubishi).

Further, if the cruising fuel consumption of the MU-300 is supposed to be 100, that of the Learjet 35 of the same class becomes 110, and that of the large aircraft Challenger becomes 180. It is claimed that the fuel consumption of the MU-300 is positively small. This depends largely on the JT15D-5 engine manufactured by Pratt & Whitney of Canada and on the newly designed main wing. Mitsubishi explains further that the operating cost will be inexpensive because consideration is also given to reduce the man hours required for maintenance and inspection.

In addition to these points, Mitsubishi emphasizes that "the MU-300 being the only home-produced aircraft" is a big difference from other business aircraft. Home-produced equipment and parts are used in the MU-300 as much as possible, not to mention the body. Since consistent development and production is conducted in Japan, quick and pertinent support is said to be possible that cannot be expected for imported aircraft and equipment. Furthermore, this is probably effective in the expansion of domestic consumption.

It is certain that there is a big advantage in easily obtaining technical support and parts supply if the manufacturers are in Japan. However, there are also some counterarguments on this point. These are opinions that the price of home-produced parts is comparatively high because the quantity of production is small, the period for overhaul is long, or, as in the case of the YS-11, the supply of parts became unstable even while the passenger plane is still in operation and the airlines supply parts to each other. In either case, it cannot be helped that there are both advantages and disadvantages.

Adaptability With Inspection Equipment

In order for the MU-300 to function as a flight inspection aircraft, ways must be considered not only to solve the problem of housing the flight inspection system in the aircraft, but also the problem of matching the flight inspection system to the aircraft. As a concrete example in considering this problem, the combination of the flight inspection system AFIS (automatic flight inspection system) of Litton Systems, Canada and the MU-300 is used. (See the January issue of this magazine for details on AFIS.)

The MU-300 system equipped with two AFIS consoles in the rear of the cabin is targeted against the TAGAN, VOR/DME, NDB, ILS, and all the various other communication and radar facilities presently used by aircraft, and it can cope with the inspection of MLS and the use of GPS, which is sure to be introduced in the future. In this system the inertia navigation system (INS) is used mainly as the self-position determination method that will become important in flight inspection work, and the navigation devices, such as the scanning DME and the automatic loran C, are used to improve and correct the precision of the systen. The TV camera newly installed at the bottom in the center of the fuselage is used in the case of ILS.

Navigation-communication equipment, etc. is housed in the rear console as the equipment for inspection in addition to the navigation-communication equipment in the cockpit. The measured data obtained from this inspection equipment are sent to the central computer after the scaling taken into the signal conditioner and the analog-digital conversion. These data are printed out or expressed on the display according to the designated form after making the statistical processing, the comparison with the expected value, and the judgment of acceptance or rejection as required. At the same time, the data are recorded in the external memory device for reexamination on the ground.

Comparison of MU-2J and MU-300

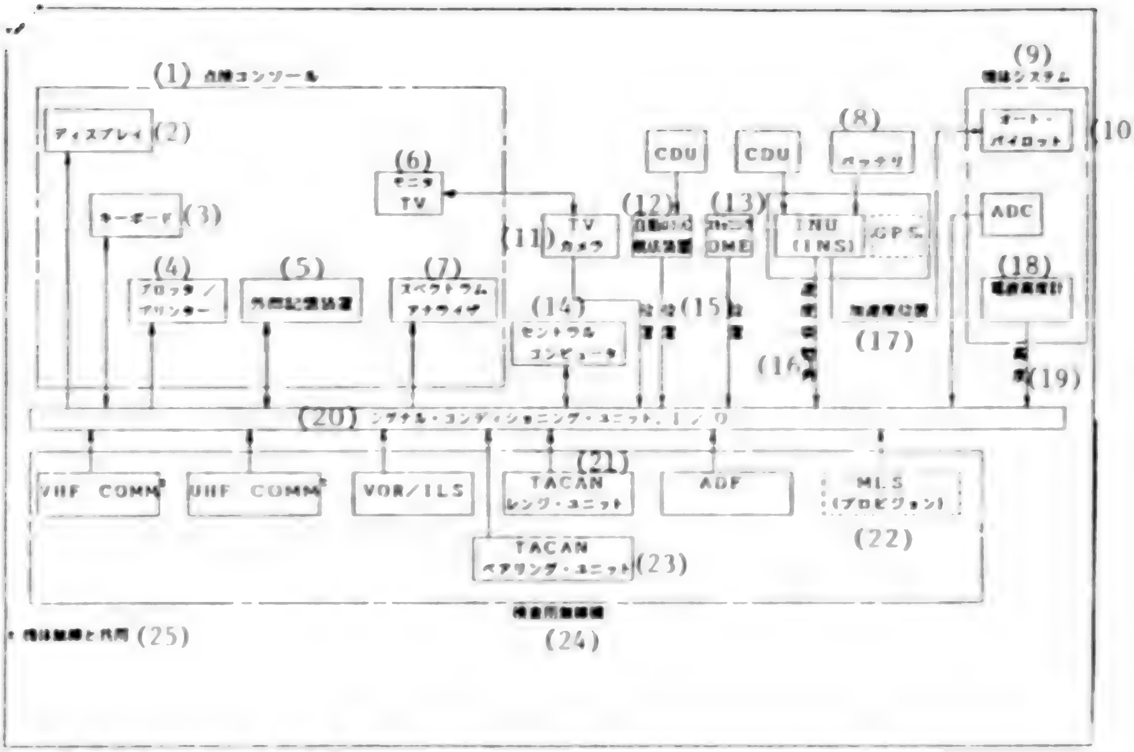
	MU-300 Flight Inspection Aircraft	MU-2J Flight Inspection Aircraft	Remarks
Inspection system	Automatic	Manual	Equipped with automatic inspection system
Maximum cruising speed	445 Kts.	295 Kts.	Standard atmosphere
Economical cruising speed	395 Kts.	260 Kts.	Standard atmosphere
Maximum operation altitude	41,000 Ft.	25,000 Ft.	
Stalling speed	88 Kts.	79 Kts.	Maximum landing weight, landing flap form
Takeoff distance	4,630 Ft.	2,080 Ft.	Maximum takeoff weight, above sea level, no wind, standard atmosphere
Landing distance	2,890 Ft.	2,250 Ft.	Maximum landing weight, above sea level, no wind, standard atmosphere
Cruising range	1,865 NM	1,060 NM	Standard Atmosphere, no wind

Further, specified pattern flights will become necessary to conduct the flight inspection of the ILS and TACAN, VOR/DME, and NDB. The MU-300 can conduct automatic flight of high-degree specified patterns by calculating the course with the computer of the INS, and by sending the command to its automatic flight control system/flight director. Further, it has a self-test program and a channel check program to judge the normal function of the inspection system prior to flight, and can judge the condition of the inspection equipment.

And, by freely using these automated systems, it will become possible to conduct much more efficient flight inspection work than the past systems by only one flight inspector with the high performance of the aircraft.

In the future, the INS + GPS hybrid navigation system, which is more precise and has a broader coverage area than the past system of INS + scanning DME + loran C, is expected to become the center of the self-position determination method.

To install these AFIS to the MU-300, it is necessary only to install various antennas and a TV camera, two consoles, the navigation-communication equipment, etc. in the rear fuselage inside and outside of the aircraft, and it is not particularly necessary to make a great change in the aircraft structure. Thus, it is believed that the combination of AFIS and MU-300 can be made without much difficulty.



飛行点検システム系統図

Flight Inspection System Diagram

Key:

1. Inspection console	13. Scanning DME
2. Display	14. Central computer
3. Keyboard	15. Position
4. Blotter printer	16. Speed attitude angle
5. External memory device	17. Acceleration position
6. Monitor TV	18. Radio altimeter
7. Spectrum analyzer	19. Altitude
8. Battery	20. Signal conditioning unit I/O
9. Body system	21. TACAN range unit
10. Autopilot	22. MLS (provision)
11. TV camera	23. TACAN bearing unit
12. Automatic loran C navigation system	24. Radio for inspection
	25. Use in common with body radio

[Boxed item, p 39]

Orders for the Aircraft are Increasing in the United States

On 2 December last year, Beech Aircraft Corporation received the franchise (excluding Japan) for the MU-300 business jet from Mitsubishi Heavy Industries, Ltd. and started selling the aircraft under the name Beech Jet. Beech Corp. became able to sell a business jet under its own brand name which the corporation had dreamed of doing for many years.

As represented by the King Air series, Beech has a line of high-powered high-class turboprops, but it did not have a business jet that is ranked higher than the turboprop.

Beech once tried to develop a business jet by itself or to sell the Hawker Sidley HS-125 (present BAe 125), but it failed to do so. The MU-300 fulfilled the long-cherished desire of Beech Corp. The fact that the Beech Corp., aspiring to a high-class aircraft, started the sale of the MU-300 means that the corporation recognized the superiority of the MU-300.

The corporation announced at this year's NBAA show that "nine Beech jets will be produced this year, and we already have buyers for seven. It is scheduled to deliver 18 Beech jets next year." But the remaining two aircraft were also sold after the show, and the situation is that the corporation can also expect to receive orders next year for a number of aircraft more than are scheduled to be produced. To cope with this situation, the two companies are seriously studying ways to increase the monthly output of aircraft from 1.5 to 2. Such an increase in orders depends greatly on the revival of business, but eventually the important things are good products and high marketability.

[End boxed item]

[Boxed item, p 40]

Put Hybrid Navigation System to Practical Use

Mitsubishi Heavy Industries, Ltd. announced on 5 November that it had established a hybrid navigation system for aircraft in cooperation with the Japan Aeronautical Electronic Industry Co., Ltd. and the Japan Radio Co., Ltd. This is a future navigation system combining the inertial navigation system using the ring laser gyro and the GPS (Global positioning system) receiver.

This new system improves the error of about 2 km an hour in the past inertial navigation system to an error within 150 m corrected by the GPS.

Further, the optical data bus system was used for the transmission and reception of the data signal by the computer, the INS, and the GPS. This is also important technology to make the fly-by-light system possible in the future.

Mitsubishi repeated the test flight from 22 September to 13 October with this system installed on the MU-300. It expects that many hybrid navigation systems of this sort will be used by military and civilian aircraft in the future.

[End boxed item]

[Boxed item, pp 40-41]

Report of Test Ride in MU-300

On the apron of the Komaki South Factory of Mitsubishi Heavy Industries adjacent to Nagoya airport, the MU-300 (Diamond I, JA 8248) we were on started taxiing slowly along the ground.

The MU-300 I test rode at this time was the No 2 aircraft used as a development test aircraft, and it is presently used as a company aircraft of Mitsubishi Heavy Industries. Therefore, the instrument arrangement, etc. in the cockpit was simpler and different from that of the aircraft that was delivered. The pilot of this flight was Mitsuo Sato, the company's chief pilot. Sato is an expert pilot who took charge of the development of the T-2, F-1, CCV, MU-300, etc.

Following the instructions from Nagoya ground control, the MU-300 taxied to the southern end of the runway. The visibility that day was 15 kilometers and it was an ideal day for a flight with almost no clouds. The final inspection prior to takeoff was conducted at the southern end of runway No 34 and the takeoff run began with the takeoff permission. The copilot read out the speed. The aircraft accelerated to V_1 (critical point speed, 101 knots), V_R (rotation speed, 108 knots), and V_2 (safe takeoff speed, 113 knots), took off, and began to climb.

Acceleration in the takeoff run was very good as expected. Sato said: "The acceleration performance of the Diamond II is further improved. I was surprised by the good acceleration of the F-86 when I changed from the T-33. There is that much difference between the two aircraft."

After leaving the traffic pattern of Nagoya airport by turning to the right, the aircraft continued climbing in the direction of north-northeast. Since the pressurizing system for the cabin works well, we felt as if we were on the ground even as the aircraft climbed at 2,000-3,000 ft/min. Since the MU-300 has a pressurizing capacity of 9.1 psi, which is higher than a passenger plane, it can keep the air pressure of 6,400 ft altitude even as it climbs to an altitude of 41,000 ft.

The aircraft shifted to level flight at an altitude of 17,000 ft. and flew to the north in view of snow covered Mt Ontake of Koso on the right side, and after a while it reached the training area extending above the northern Japan Alps. The meteorological radar set at the ground mapping mode on the aircraft indicated Noto Peninsula on course ahead.

Sato first made a 2G turn by a 60° bank and a lazy eight to demonstrate the maneuverability of the MU-300. I particularly noted the turning performance in these flight subjects. The MU-300 uses the side control system by the spoiler like the MU-2 to improve its takeoff and landing and low speed performance because some pilots pointed out a somewhat poor response of the side control in the MU-2. Actually experiencing the turning

of the MU-300, one cannot tell that it has spoiler control as it is completely the same as aileron control. When the speed brake (the spoiler is also used) is used, if anything, the feeling of the control becomes better, but on the other hand, it feels heavier.

The aircraft continued low-speed flight. It reduced speed to 12 knots by closing the throttle. One of the characteristics of the MU-300 is that it can fly in a wide speed range from the maximum cruising speed of 461 knots to the minimum operation speed of 89 knots. Sato showed us the good low-speed controllability and stability of the MU-300 by repeating right and left turns maintaining a speed of 120 knots.

Further, the force of the elevator is lightened by using the elevator trim tab according to the change of speed, and the switch of the trim tab of the MU-300 is devised. It is built in the control stick like an ordinary tab switch, but it will not function unless actuated after pushing the switch once, and if the switch is kept acuated over 5 seconds, it is automatically switched off. It is set to prevent incorrect actuation of the trim tab, but since it is not adopted on many other aircraft, one will be confused at first, but will soon become accustomed to it.

Stalling will be discussed next. Generally in stall training, the recovery operation starts when the control stick is vibrated by the shaker, but on this occasion the speed was reduced until the aircraft was completely in a stalling condition. The aircraft was made to stall in the respective conditions of cruising--first at 10 degrees lowering of the flaps, next at 30 degrees flap lowered, and of lowering the landing gear. In any case, the stalling is known beforehand by the vibration of the control stick by the shaker, then the aircraft is in a stall condition and by loosening the control stock it lowers its nose recovering from the stall condition. There were no bad features such as being pulled to the right or left while stalling, and the aircraft recovered from the stalled condition very smoothly. Of course, there were no indications such as deep stall. It is said that the stall characteristics of this aircraft were evaluated as "excellent" by the flight mode examiner in the FAA mode certificate acquisition test.

After completing the demonstration course we decided to return to Nagoya airport. Automatic control flight was conducted on the way home using the autopilot. Sato evaluates the general characteristics of the MU-300 as being close to that of a Cessna Citation I, and says that one who can steer a reciprocal, twin-engine aircraft can easily control an MU-300. The FAA pilot who conducted the formality certification test is said to have highly evaluated the good controllability of this aircraft saying: "The MU-300 will not crash unless the pilot makes a mistake." The reporter was also certainly impressed that the MU-300 is a business aircraft with excellent controllability and stability.

The aircraft approached the No 34 runway with the guidance of the ILS at Nagoya airport. It seems that the lowering of the landing gear is more effective than using the speed brake for deceleration. The aircraft touched down easily lowering the flaps and reducing speed. It then taxied decreasing speed on the short taxiway using the speed brake and the landing gear brake. Sato told of his experience when he landed against a strong side wind of 33 knots in the United States operating an MU-300, stating that it was not an especially difficult landing.

It is unfortunate that such an excellently performing business jet with good controllability, manufactured in Japan, cannot be used in the major airports of Tokyo and Osaka. If they could be freely used at these airports, more MU-300's would probably be sold.

[End boxed item]

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APPLICATIONS OF CONDUCTIVE POLYMERS TO HUMIDITY SENSORS

Tokyo KINO ZAIRYO in Japanese Nov 86 pp 17-27

[Article by Noriyuki Kinjo and Toru Sugawara, chief researchers, and Syuichi Oohara and Shigeki Tsuchitani, researchers, Hitachi Research Institute, Hitachi, Ltd.: "The Principle of Operation of a Humidity Sensor--Polymers Desirable as Moisture Sensitive Materials"; first paragraph is editorial introduction]

[Text] Along with the remarkable progress in electronics, the necessity for sensors for functional improvement of various devices is on the rise. As part of it, the development of humidity sensors to control human living environment or workingspace is required. This paper introduces the principle of operation of a polymeric humidity sensor and outlines the chemical structure of polymers sensitive to humidity.

1. Preface

Humidity and temperature are important factors which control human living environment and attempts to detect humidity have been made since ancient times. On the other hand, parallel to remarkable progress and development of electronics technology in recent years, sensors necessary for improvement in the function of electrical devices have been called for. In the environmental control and quality control sectors, humidity sensors with high reliability, in particular, are strongly desired. Household electrical appliances such as room air conditioners and dehumidifiers and air conditioning for buildings provide a pleasant environment by controlling humidity, while the electronic parts manufacturers and the textile industry have the humidity range suited for improving the quality of their products; this is why much importance is attached to stable humidity control.

Humidity sensors can be largely divided into an expansion type, wet- and dry-bulb type, electric resistance type, capacitance type, dew-point type and electromagnetic wave absorption type. In recent years, there have been many reports on electric resistance types. This type can receive electric signals, allow easy connection with microprocessors, is compact and light weight, and has a simple structure.

Of the electric resistance type humidity sensors, the first was the Dunmore type released in 1983. Since then various humidity sensitive materials such

as electrolytes, organic polymers, semiconductors, and metallic oxides have been developed. Of these, many reports have been made on metallic oxides recently. We considered that humidity sensors with a humidity sensitive film of polymeric electrolyte, one not much studied, could have great potential for long-term stability, therefore, they were trial-manufactured and studied. The following is a report on the results.

2. Principle of Humidity Sensitive Operation

Figure 1 shows the typical operating principle of a humidity sensor with polymers applied. A dry polymeric electrolyte is an insulator, and when it absorbs moisture, dissociation results even if it is solid. When a polymeric electrolyte in such a state is impressed, a polymeric ion with great molecular weight does not move, but a low-molecular counter ion moves to be an electric charge carrier, thereby causing conductivity. Thus, application of change in electric resistance values of polymeric electrolyte by moisture absorption and dehumidifying can permit external humidity to be detected. Basic characteristics of a practical humidity sensor are as follows:

(1) Change in electric resistance by humidity (humidity sensitive characteristic).

(2) Capability of following external humidity change (responsibility).

(3) Long-term reliability (life and environmental resistance).

The relation between the chemical structure of a polymeric electrolyte and changes in these basic characteristics of a humidity sensor is an important aspect in developing humidity sensitive materials. An important index for the development of humidity sensitive materials is the degree of affinity of polymers for water, namely, a degree of hydrophobic and hydrophilic properties. In this context, nonionic, cationic, and anionic monomers with different degrees of hydrophobic and hydrophilic properties were selected, properly combined ionic copolymers were synthesized, and a study was made on the correlation between chemical-structural factors of these polymers and their characteristics as humidity sensitive materials.

An ionic copolymer was synthesized by radical copolymerization of nonionic monomers with ionic monomers in a hydro-medium. Nonionic monomers styrene (St), methyl methacrylate (MMA), methyl acrylate (MA), and hydroxy ethyl methacrylate (HEMA) were used. Anionic monomers methacrylic acid (MAA), acrylic amide-2-methyl propane sulfonic acid (AMPS), styrene sulfonate (NaSS) were used, while cationic monomers methacryloil oxyethyldimethyloctyl ammonium chloride (MEDMOcACl), methacryloil oxyethyl trimethyl ammonium chloride (METMACl), and methacryloil oxyethyldimethyl ammonium chloride (MEDM-ACl) were used. Polymerization initiators azobis isobutyl amidine hydrochloride (AIBA) and potassium persulfate (PPS) were used for synthesizing cationic copolymers and anionic copolymers, respectively. Table 1 shows the chemical structural formulas of their reagents. The monomers shown in Table 1 are arranged from left to right in ascending order of hydrophilic property. For the details of the experiments, please refer to the previous report.

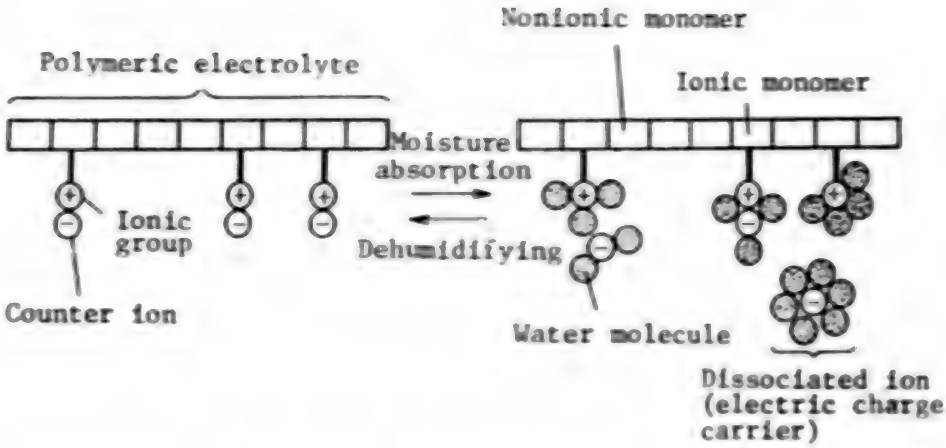


Figure 1. Operational Principle of Humidity Sensor Using Ionic Conductive Polymer (Conductivity generating mechanism)

Table 1. Chemical Structure of Monomers Used for Synthesis

	Hydrophobic property → Hydrophilic property			
Anionic monomer	MAA: $CH_2=C(COOH)-CH_3$	AMPS: $CH_2=CH-C(=O)-N(H)-C(CH_3)_2-CH_2-SO_3H$	NaSS: $CH_2=CH-C_6H_4-SO_3Na$	
Cationic monomer	MEDMOcACl: $CH_2=C(CH_3)-COOC_2H_4N(CH_3)_2(C_8H_{17})Cl$	METMACl: $CH_2=C(CH_3)-COOC_2H_4N(CH_3)_2(CH_3)Cl$	MEDMACl: $CH_2=C(CH_3)-COOC_2H_4N(CH_3)_2(H)Cl$	
Nonionic monomer	St: $CH_2=CH-C_6H_5$	MMA: $CH_2=C(CH_3)-COOCH_3$	MA: $CH_2=CH-COOCH_3$	HEMA: $CH_2=C(CH_3)-COOC_2H_4OH$

Hydrophilic property ↕ Hydrophobic property

3. Characteristics of Humidity Sensor

Humidity Sensitive Characteristic (Electric Resistance Characteristics)

Electric resistance values and hygroscopic ratios of an ionic copolymer show remarkable difference depending on copolymerization ratios as well as external humidity. Figure 2 shows how the electric resistance and coefficient of Poly (NaSS-co-St) with different copolymerization ratios change against relative humidity. In any copolymer, when the relative humidity increases, the hygroscopic ratio increases, while the electric resistance value decreases in terms of exponential function. As to the copolymerization ratio, the hygroscopic ratio increases, while the electric resistance decreases, as the ratio monomer unit NaSS in a copolymer becomes greater. Likewise, this trend is generally observed in copolymers synthesized using other monomers, which shows that the ionic concentration of a copolymer influences the hygroscopic ratio and electric resistance value. In other words, it can be said that a humidity sensitive material with a given electric resistance value required on a circuit can be supplied by controlling the copolymerization ratio.

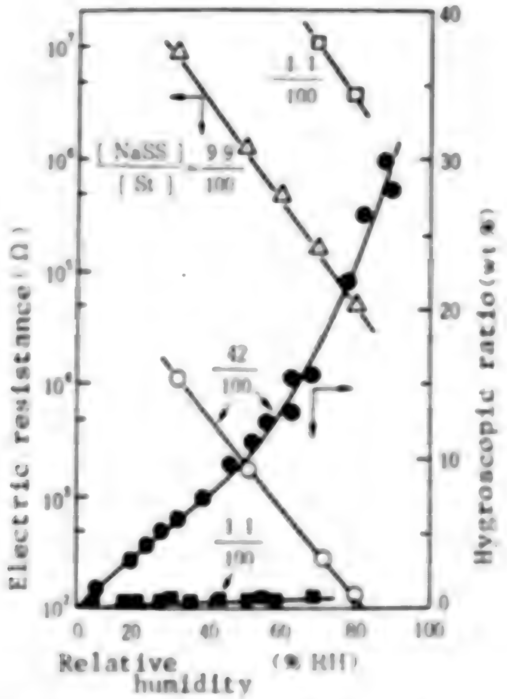


Figure 2. Humidity Sensitive Characteristic and Hygroscopic Isotherm of Poly (NaSS-co-St)

Figure 3 shows the humidity sensitive characteristic when an ionic monomer unit in a copolymer is fixed on NaSS and the nonionic monomer is changed with the copolymerization ratio kept almost constant. The electric resistance does not differ significantly with different types of nonionic monomers, while the

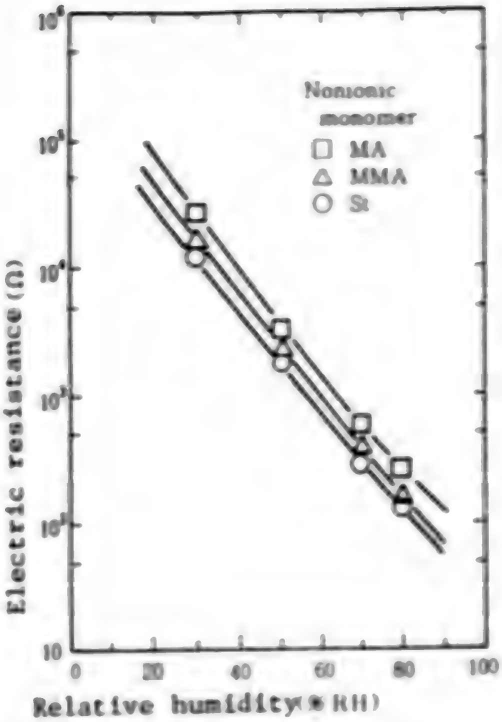


Figure 3. Influence of Type of Nonionic Monomers on Humidity Sensitive Characteristic of Polystyrene-Sulfonate Copolymer

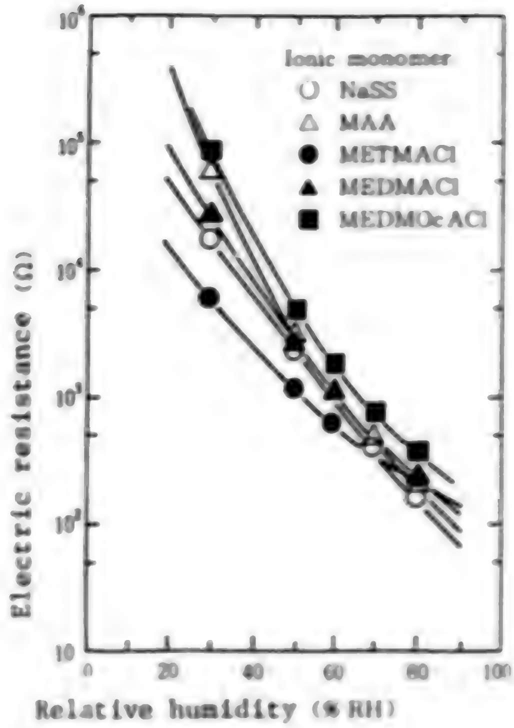


Figure 4. Influence of Type of Ionic Monomers on Humidity Sensitive Characteristic of Polymethyl Methacrylate Copolymer

resistance of those with high hydrophilic property (MA>MMA>St) tends to become slightly greater. On the other hand, the hygroscopic ratio of different types of nonionic monomers do not differ greatly from one another. Therefore, under the same relative humidity, the strong hydrophilic property of a nonionic monomer will cause a hygroscopic quantity of this part to increase relatively and a hygroscopic quantity of the ionic group to decrease as much. As a result, it is considered, dissociation of the ionic group may be caused, thereby resulting in slightly higher electric resistance.

Figure 4 shows the relation between the electric resistance and relative humidity of a copolymer when its copolymerization ratio is kept almost constant, nonionic monomers in a copolymer are fixed on MMA, and the type of ionic monomer units are changed. A difference in electric resistance values tends to be great due to the presence of ionic monomers in low humidity and the relatively small amount of ionic monomers in high humidity. The reason for this may be as follows. In high humidity, any ionic copolymer absorbs sufficient moisture to allow full dissociation to be made, so that the difference in electric resistance values between different types of ions is small. In low humidity, however, moisture absorption is controlled, so that the type

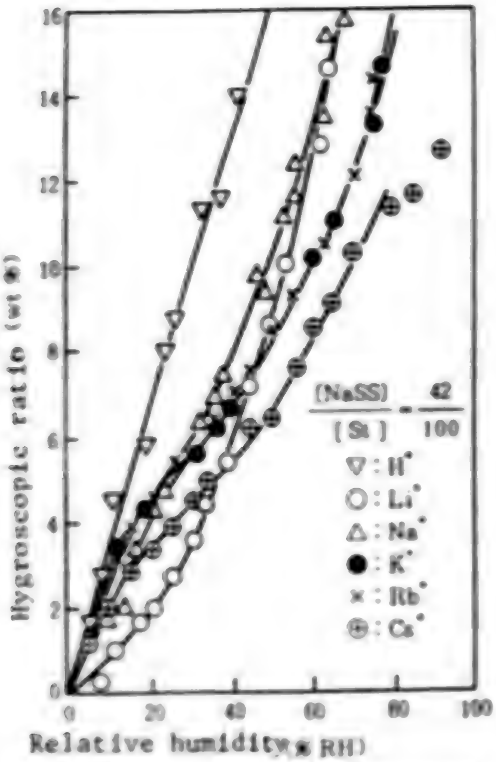


Figure 5. Hygroscopic Isothermal Curves of Copolymer of Styrene Sulfonic Acid and Styrene, Having Different Counter Ions

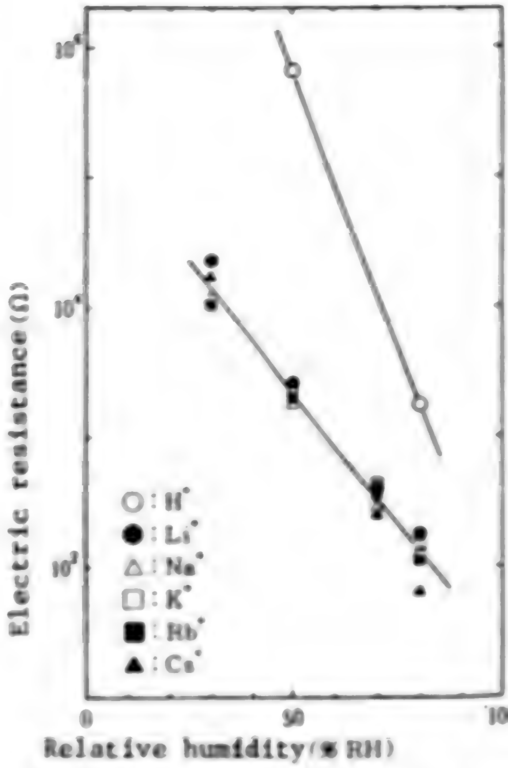


Figure 6. Hygroscopic Isohumid Curves of Copolymer of Styrene Sulfonic Acid and Styrene, Having Different Counter Ions

of ions affects dissociation significantly, resulting in a difference in the electric resistance value.

Figure 5 shows the relation between the relative humidity and hygroscopic ratio when counter-cationic species alone of anionic group (sulfonic acid group) in an anionic copolymer synthesized from SS and St is changed, while Figure 6 shows the relation between the relative humidity and electric resistance. Excepting Li^+, in almost any humidity, the greater the ionic radius of a counter ion a copolymer has, the lower its hygroscopic ratio of moisture absorption, so the type of counter ions is also responsible for moisture absorption. On the other hand, with the exception of the case with H^+, a difference in electric resistance between different types of counter ions is not very significant, and when the relative humidity is the same, the type of counter ions does not affect electric resistance significantly. A great difference between the relative humidity and electric resistance characteristic when a counter ion is H^+ and those when it is an alkali metallic ion is, it is considered, because when a counter ion is H^+, the ionic part of a copolymer is acid, while when it is an alkali metallic ion, the ionic part is salt, and acid and salt are different in the degree of dissociation of a counter ion.

Chemical Structure and Responsibility of Ionic Copolymer

A response characteristic which shows how fast to follow changes in ambient temperature is a very important point for practical use of sensors. Figure 7 shows an example of lapse change in humidity sensor display when relative humidity is changed from 40 to 60 percent (hygroscopic process) and from 60 to 40 percent (dehumidifying process). From this result two pieces of important information can be obtained; one is that individual types of humidity-sensitive materialsdiffer significantly in their responsibility, and the other is that there is more of a delay in response in the hygroscopic process than in the dehumidifying process. A study was made on the influence of a copolymerization ratio and the type of ionic and nonionic monomers on the response characteristic showing that a copolymerization ratio was an unimportant factor. As for the influence of nonionic monomers, they permit quick responsibility to be obtained roughly in ascending order of speed as follows. That is, hydrophilic nonionic monomers are more advantageous in terms of response characteristic.

HEMA > MA > MMA > St

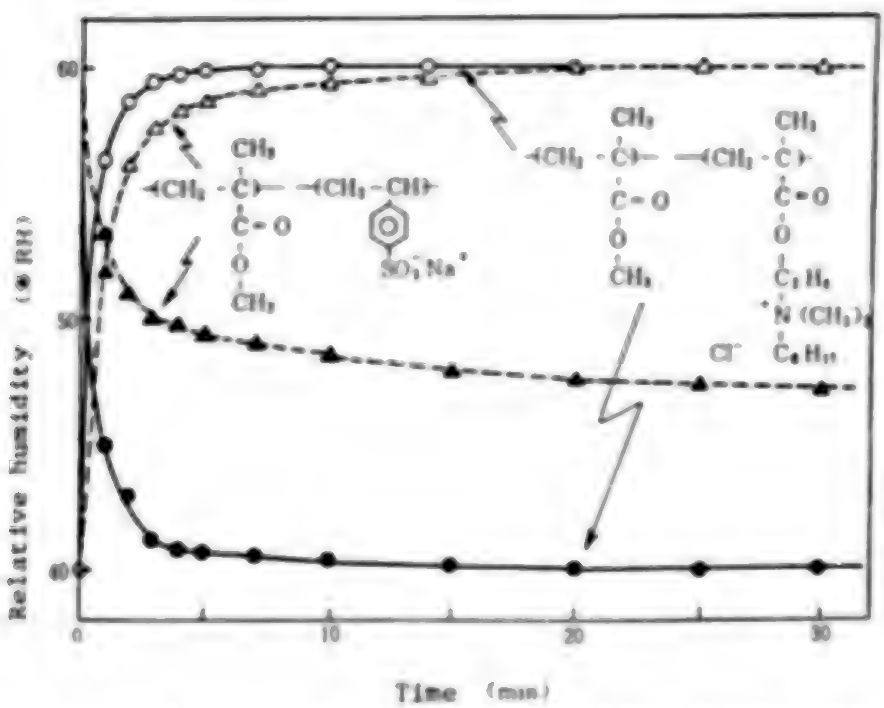


Figure 7. Comparison of Responsibility Between Humidity Sensors With Different Humidity Sensitive Materials

Time Hygroscopic process 40% to 60% —○— —△—

Dehumidifying process 60% to 40% —●— —▲—

Response time

Long ←——————————————→ Short

$$-SO_3^- > -CO_2^- > -C_2H_4\overset{+}{N}(CH_3)_2 > -C_2H_4\overset{+}{N}(CH_3)_2 > C_2H_4\overset{+}{N}(CH_3)_2$$

with H, CH_3 and C_8H_{17} respectively as the substituents on N.

Table 2. Response Time of Poly-Methyl-Methacrylate Copolymer, Each Having Different Ion Group

Copolymer			Response time (min)	
Ionic M_1	Nonionic M_2	$\frac{[M_1]}{[M_2]}$	Sorption process	Desorption process
NaSS	MMA	0.56	40	>180
NaAMPS		0.25	20	>180
NaMA		0.44	10	>180
MEDMACl		0.54	5	50
METMACl		0.14	2	6
MEDMOcACl		0.55	2	3.5

Humidity change: 60 percent RH to 40 percent RH (dehumidifying), 40 percent RH to 60 percent RH (moisture absorption)

It has been found that factors having the greatest influence on the response are ionic monomers, with the result shown in Table 2. In this table, response time was defined as the time needed to indicate an electric resistance value in relative humidity corresponding to 95 percent of a relative humidity change. In any case, response time is shorter in the hygroscopic process than in the dehumidifying process, while cationic copolymers are better in responsibility than anionic copolymers. Hydrophobic ion groups tend to be faster in response time.

This permutation can be construed as follows: A hydrophobic ion group with strong affinity with water has a strong force of binding water molecules, so that the mobility of water molecules decreases. Therefore, diffusion of water molecules in an ionic copolymer is suppressed to decrease sensor response. In other words, it is considered that the affinity between ion groups and water molecules or the diffusivity of water molecules around ions due to the affinity contributes greatly to the response of humidity sensitive materials.

State Analysis of Hygroscopic Water

Figure 8 shows the result of a differential scanning thermal analysis (DSC) made on samples obtained by having the copolymers used in Figures 5 and 6 undergo moisture absorption in an atmosphere of 30°C and relative humidity of 80 percent. In the copolymers having counter ions (including K^+ and Rb^+ not shown in the figures), a melting peak of hygroscopic water did not exist. Similar phenomena were observed in ionic polymers with other chemical structures, so that it can be said that most of hygroscopic water undergoing moisture absorption in relative humidity of below 80 percent is bound water and no free water exists--it is in a state of so-called nonfreezing bound water.

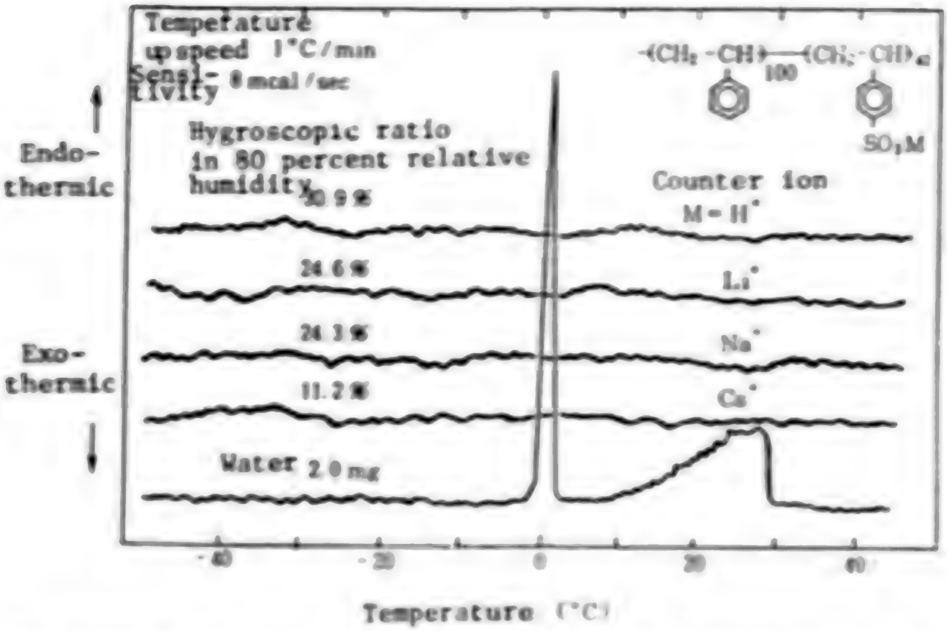


Figure 8. DSC Chart of Hygroscopic Water in Copolymer Having Undergone Moisture Absorption in Relative Humidity of 80 Percent

The hygroscopic ratio of polystyrene corresponding to the structure without ionic part of the copolymers comprising SS and St (Figure 6), in the relative humidity of 80 percent is 0.6 percent; this is very small compared with that of the copolymers with ionic part shown in Figure 5. From these facts, it can be assumed that most hygroscopic water in an ionic copolymer is adsorbed on its ionic part; i.e., most of hygroscopic water can be regarded as bound hydrate water.

Then, an analysis was made of the binding intensity against bound water of the same copolymer used for the study of DSC by nuclear magnetic resonance (NMR) spectrum. Two absorption examples were studied, with the results shown in Figure 9. The absorption in the wide part is about 7G wide, assigned to hydrogen atoms, its line width having the same value as PSt, and relying neither on the type nor hygroscopic ratios of the counter ions. In the narrow part, absorption is assigned to hydrogen atoms of hygroscopic water molecules, and when the hygroscopic ratio is around 1 percent, the smaller the ion radius of a counter ion a copolymer has, the greater the line width, except for H. This shows that the smaller the ion radius of a counter ion is, the stronger a hydroadmolecule is bound. This is because the smaller ion radius a counter ion has, the higher the surface density of charge is, causing water molecules to be adsorbed readily by electrostatic interaction. When a hygroscopic ratio becomes great, a line width becomes as great as that of ordinary water, irrespective of the type of counter ions. The similar relation between a hygroscopic ratio and a line width has been found also with ionic copolymers with other chemical structures, which shows that the greater a hygroscopic ratio becomes, the weaker a binding force of an ion over hygroscopic water molecules becomes.

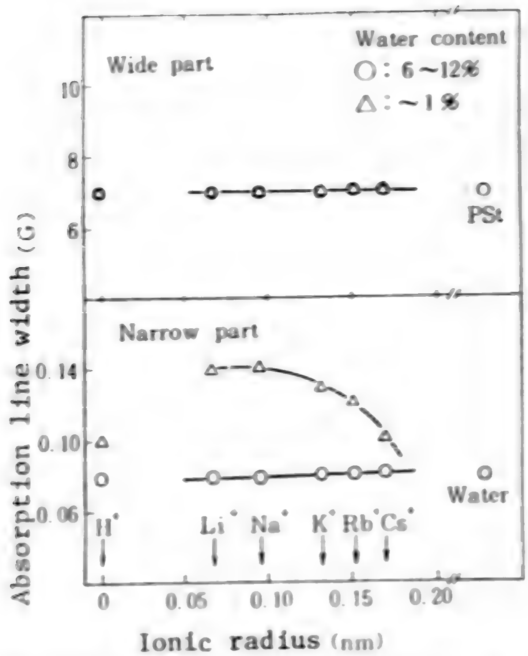


Figure 9. Absorption Line Width of NMR When Copolymer of Styrene Sulfonic Acid and Styrene, Different in Counter Ion Group, Has Undergone Moisture Absorption

An absorption line width is below 0.15G though it relies on a hygroscopic ratio, which means that though hygroscopic water molecules are so-called nonfreezing bound water, they are in a liquid state in terms of ease of motion. This suggests that a dissociated ion can function as an electric charge carrier because it can exist in a liquid state, demonstrating the operating principle shown in the humidity sensor in Figure 1.

A Study on Hygroscopic Conductive Mechanism

Studies done so far assume that most water molecules which have undergone moisture absorption by an ionic copolymer are adsorbed to the ionic part, causing counter-ions and ion groups to be dissociated, and these dissociated ions contribute to conductivity. The mobility of ion groups in covalent bond with a copolymer is assumed to be very small compared with the mobility of counter ions, so that migration of counter ions, particularly dissociated ions, is important for conduction. Assuming that the Stokes' law can be applied to the migration of counter ions in a copolymer, electric resistance R can be expressed in the following expression:

$$R = A \cdot \frac{\eta r}{\alpha C \left(e - \frac{f}{E}\right)} \quad \cdots\cdots \qquad (1)$$

where, A is a constant on the shape of a humidity sensor element, etc., η is the internal coefficient of viscosity of a copolymer, r is the Stokes' radius of a counter ion, α the degree of dissociation of a counter ion,

C is the concentration of a counter ion, f is the force working on counter ions through interaction between ions, and E is the electric field.

From Figures 5 and 6, a relation between the hygroscopic ratio and electric resistance of an anionic copolymer comprising SS and St with various counter cations can be shown in Figure 10, while Figure 11 shows a similar relation of a cationic copolymer consisting of METMA and MMA having various counter anions. With any of these copolymers, only the type of counter ions was changed, the concentration of counter ions remained constant.

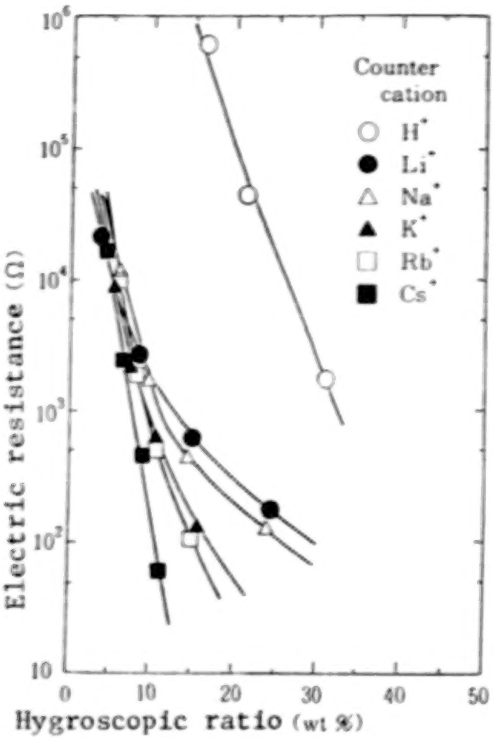


Figure 10. Relation Between Electric Resistance and Hygroscopic Ratio of Copolymer of Styrene Sulfonic Acid and Styrene, Each Having Different Counter Ion Group

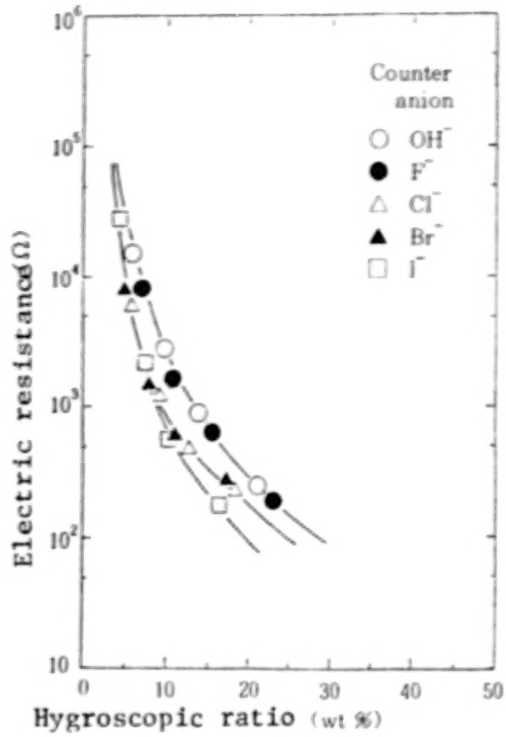


Figure 11. Relation Between Electric Resistance and Hygroscopic Ratio of Copolymer of METMA and MMA, Each Having Different Counter Ion

Let us take a look at the effect of the type of counter ions when hydroscopic ratios are equal. When counter ions are alkali (Figure 10), the smaller the ionic radius, the greater electric resistance; i.e., it is suggested that the smaller the ionic radius, the less its ease of migration or the more difficult its dissociation. Look at it from the standpoint of a hygroscopic ratio necessary for an equal-resistance state, and it is found that the smaller the ionic radius of a counter ion, the more water it must absorb to show the same electric resistance. This trend is the same when a counter ion is halogenated

anion (Figure 11), but not so remarkable as alkali cation due to anion's ionic radius not being so great. From what has been stated so far, the following study can be made on the expression (1) showing a correlation between a dissociation degree, ionic radius, hygroscopic ratio, and electric resistance.

A small counter-ionic radius results in great surface density of charge, so that:

(1) A great quantity of hygroscopic water is needed for dissociation (it becomes a matter of a degree of dissociation α in the expression (1)).

(2) Strong binding of hygroscopic water results in insufficient ease of migration of ions to make them less able to migrate (it becomes a matter of viscosity η in the expression (1) though the result of NMR in Figure 5 may support this study).

(3) Ions become large for those having undergone hydration and are subject to great resistance (it becomes a matter of the Stokes' radius r).

Which of these three factors is the most dominant is not clear at present and remains an important theme for future study.

Application Examples and Future Deployment

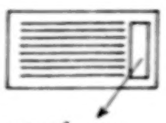
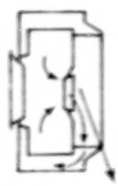
Application Examples

Humidity sensors applied to products are constructed, as seen in Photo 1-(a) [omitted], with polyelectrolyte applied on a comb metallic electrode and a permeable protective coat applied to the electrode. Application examples are shown in Table 3. They are all familiar household electric appliances, and application was aimed at operating these electric appliances more efficiently by detecting humidity. With air conditioning equipment such as air conditioner, dehumidifier and humidifier, amenity and economizing on energy within residences can be pushed for, while with clothing dehydrators, economizing on labor and energy can be pushed for by setting them so they automatically stop in the dry state where ironing can be done with ease.

Future Deployment

Being polyelectrolyte, a humidity sensitive film polarizes to cause electrolysis when DC voltage is impressed. To avoid this, an oscillating circuit capable of impressing AC voltage is necessary. In addition, humidity cannot be detected correctly without temperature compensation using a thermistor (thermal sensor), etc., since an electric resistance value in general is temperature dependent, and connecting a thermistor to equipment requires a current amplifier circuit. That is, practical use of the humidity sensor in Photo 1-(a) [omitted] needs an electric circuit corresponding to itself to be used separately. In the future humidity sensors will have all these electric circuits arranged on a single substrate. Photo 1-(b) [omitted] is an example of thermal-hygro compound sensor, combining a humidity sensor, thermal sensor,

Table 3. Product Application Examples of Humidity Sensor

Applied product	Air conditioning equipment			Housekeeping equipment
	Room air conditioner	Dehumidifier	Humidifier	Clothing dehydrator
Effect resulting from added humidity sensor	Automatically controls dehumidifying operation to control futile consumption of electricity	Displays proper state of humidity, operates so as to retain it, and controls electricity	Operates automatically to reach desirable set humidity and can display current humidity	Can select dryness suited for ironing, elaborate drying and drying degrees of standard and thick clothing
Humidity sensor mounting situations	Front view of interior unit  Mounted on control substrate to detect humidity of indoor-intake air	Slant view  Mounted at bottom of operating panel to detect room humidity	Slant view  Mounted on control substrate to detect room humidity	Longitudinal section  Mounted in rear of rotary drum to detect humidity of cyclic air

and signal processing circuit on a ceramic substrate capable of entering digitalized output into a microcomputer.

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